Systematic Education:

OR,

ELEMENTARY INSTRUCTION

IN

THE VARIOUS DEPARTMENTS

OF

LITERATURE AND SCIENCE;

WITH

Practical Rules

FOR STUDYING

EACH BRANCH OF USEFUL KNOWLEDGE.

BY THE REV. W. SHEPHERD,
THE REV. J. JOYCE,
AND THE REV. LANT CARPENTER, LL.D.

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OF

VOL. II.

PRACTICAL ESSAY, &c.

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ON NATURAL PHILOSOPHY.

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IN a course of natural philosophy, it is usual to place Mechanics at the head, because much of every other department depends upon the right apprehension of the theory of this. Mechanics may be defined "the science which treats of the laws of the equilibrium and motion of solid bodies; of the forces by which bodies, whether animate or inanimate, may be made to act upon one another; and of the means by which these may be increased to almost any degree." As the practical part of this science is closely connected with the arts of life, and particularly with those which existed even in the rudest ages of society, the construction of machines must have been understood and practised in some way or other, long before any theory could have been invented, or even thought of. Hence, at a very early period, we read of the use of the lever, the pulley, the capstan, and other simple machines, long before the principles of their action could

have been investigated. In the remains of Egyptian architecture, there are the most striking marks of mechanical invention. The elevation of ponderous, and almost immense masses of stone, to very great heights, seems to have required an accumulation of force and mechanical power with which modern architects and mechanics are unacquainted.

The theory of Mechanics, next to that of Geometry, is reckoned the most certain: generally speaking, it proposes for consideration, Time and Force, or Power; and the following properties of matter, viz. extension, figure, impenetrability, mobility, and inertia. The application of this science to the various practical purposes in human life, leads to many branches of inquiry; such as the nature of machinery, the advantages, and disadvantages of different materials, the effects of friction, &c. All which will merit the attention of the student in Natural Philosophy, though the limits of our work will not permit us to do more than take a cursory notice of them, and then refer to works of authority in which the subjects are discussed at large.

The first traces that we have of any thing like theory in this branch of science, is in a work of Archimedes on "Equiponderants," in which he considers a balance supported on a fulcrum, having a weight in each scale; and taking as a fundamental principle, that when the two arms of the balance are equal, the two weights supposed to be in equilibrio, are also equal, he shews, that if one of the arms be increased, the weight applied to it must be proportionally diminished. Hence he arrives at the general conclusion, that two weights, suspended to the arms of a balance of unequal length, and remaining in equilibrio, must be reciprocally proportional to the arms of the balance. This is the first trace, any where to be met with, of a theoretical investigation of mechanical science. Archimedes did not, however, stop here; he advanced, from step to step, till he was enabled to find the centre of gravity of various bodies; and to him his contemporaries were indebted for the theory of the inclined plane, the pulley, and

the screw, besides the invention of several machines, of which, unfortunately, scarcely any thing is now known.

From the time of Archimedes till the commencement of the sixteenth century, little was done to advance the theory of mechanics. About this period, Stevinus, to whom we have before referred, made many discoveries in the laws of equilibrium, which the great Galileo carried much farther. This philosopher, who flourished at the end of the sixteenth, and the beginning of the seventeenth centuries, laid the foundation of almost all the discoveries which have succeeded each other, for more than two centuries. He investigated the laws of accelerating forces; and shewed the nature of the curve which is described by a projectile: he inferred, from observation, the isochronism of the vibrations of a pendulum, and the principle was soon applied to the regulation of chronometers.

The laws of collision, another branch of mechanics, were investigated nearly at the same time in England by Wren and Wallis, and in France by Huygens. Next to the discoveries of Archimedes and Galileo, those of Huygens hold the third place in the order of time, and may be ranked among the greatest benefits that have been conferred on science. His investigations of the cycloid, and his doctrine of central forces, were the immediate foundation of Sir Isaac Newton's improvements. Hooke was great as a mechanician; his inventions were numerous, and very important in the history of mechanics.

Dr. Barrow, in his lectures, treated at large of the composition of motion, and other mechanical subjects. He was professor of mathematics at Cambridge, an office which he willingly resigned, to make way for the immortal Newton, whose whole life was a life of discovery: to say nothing of the other topics which he explained and illustrated, his theory of gravitation, and the mechanics of the universe, are developed in his Principia, first published in 1687. He considers in that work the subject in its utmost extent; and contem-

plates every conceivable variation of moving force, and determines the motion resulting from its actions. His first application of these doctrines was to explain the celestial motions; and the magnificence of this subject caused it to occupy, for some time, the whole attention of mathematicians. But the same work contained propositions equally conducive to the improvement of common mechanics, and to the complete understanding of the mechanical actions of bodies. Sir Isaac Newton lived to a great age, and had, says Fontenelle, "the singular happiness of obtaining, during life, all the credit and consideration to which his sublime researches, and his fortunate discoveries, entitled him. All men of science, in a country which produces so many, placed Newton, by a kind of acclamation, at their head." The Bernoullis on the continent were successfully pursuing the same studies with the illustrious English philosopher, and the general laws of mechanics were very elegantly investigated and applied by these contemporary philosophers, while Machin, Cotes, Halley, and De Moivre, were applying themselves at the same time to similar pursuits. Several members of the Academy of Sciences at Paris, were the authors of various useful investigations relating to practical mechanics; but not many of these were given to the public till after the year 1700; some of their inventions made their appearance much later, in the "Collection of Machines," approved by the Academy; and some of them have been inserted in a work published at Leipsic, under the title of "Theatrum Machinarum." Throughout the whole of the last century, the Transactions of various societies, established for the promotion of science, became every year more numerous; and the publication of literary and philosophical journals at Leipsic and Paris, formed a mode of communication which was extremely serviceable in facilitating the dissemination of all new discoveries.

In our own country, we have had, during the last century, a great number of instances, in which practical invention, and the most comprehensive science, have been united; and

hence that branch of natural philosophy, *Mechanics*, has been carried almost to the acmè of perfection. It remains for us, in this division of our volumes, to give a very slight sketch of the leading subjects comprehended under each department of natural philosophy, and then point out the works in which they may severally be most successfully studied by persons of all ages.

Under the article Mechanics, has usually been included an illustration of *matter* and its properties, considered as the substratum of the science, as that which acts on our senses, either immediately, or by the perceptible effects which it produces upon other bodies: matter is divided into that which is capable of being seen, by reflecting the rays of light to our eyes; and that which, by its transparency, is always invisible; such is the atmospheric air, with which we, and all terrestrial bodies, are perpetually surrounded, and such are the chemical gases, hereafter to be described.

Hence we come to the properties of matter; as solidity, impenetrability, divisibility, mobility, and inertia, which belong to all bodies whatever. From these, we are led to the consideration of *motion*, and to the laws by which it is governed when *accelerated*, and when *retarded;* to shew that in these and other cases which occur, it is to be estimated by the spaces run over, and that the velocity of motion is measured by the space passed over in a given time. From this, we are led to consider the effect produced on the motions of bodies, by the actions of one or more forces in the same, or different directions, and in what instances motion is carried on in straight lines, and in what in a curve.

The different kinds of *attraction* claim the attention of those who study mechanics as a science, though it is with the attraction of cohesion and gravitation that they are chiefly concerned, of which the latter is introductory to the knowledge of *central* forces, divided into (1.) the *centrifugal*, which is defined as the tendency that bodies revolving round a centre, have to fly off from it in a tangent to the curve they move in: and (2.) the centripetal force, or that which is continually

impelling to a centre, such is the attraction of gravitation, whether the centre be that of the *earth,* to which all terrestrial bodies, and the moon likewise, have a tendency; or that of the sun, to which the earth and other planets, with their satellites, tend, and would fall, if the action of the centrifugal force were suspended.

The principle of gravitation being established, without pretending to say what that principle is, the student is led to reflect upon the *centre of gravity,* which exists in bodies, and in which the whole weight of a body may be said to be collected, because, if that be supported, the whole body is supported; and upon the *line of direction,* or that path through which a body, left to itself, falls towards the centre of attraction, whether it be of the earth or the sun.

These preliminaries being understood and established, and which are amply illustrated in a hundred different elementary works, the student goes on to the consideration of the mechanical powers, viz. the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw; since to these simple machines, all others, however complicated, may be reduced: we shall here describe them as briefly as possible.

The *Lever* is only a straight bar of iron, wood, or other material, supported on, and moveable round a point called the fulcrum, or prop. In regard to this mechanical power, three things are to be considered, viz. the fulcrum by which it is supported; the weight to be raised, or resistance to be overcome; and the power by which this is effected.

The lever is distinguished into three kinds: 1. When, in the lever A B, the prop F, Plate I. fig. 1, is placed between the power P and the weight W. The lever is supposed capable of turning about on F, and there will be an equilibrium, or the two ends will balance one another, when the weight W, multiplied into the distance F B, is equal to the power P, multiplied into the distance A F. For two bodies will always balance one another, when their momenta, or

quantities of force are equal. Now the momentum of a body is always in proportion to its weight multiplied into its velocity.

Suppose A B, fig. 2, to be the lever, and turned into the situation C D, as the end A is farthest from the fulcrum F, it must have travelled over a greater space in coming to D, than B has in coming to C; but the velocities are as the space passed over in the same time, therefore the velocity of A must be greater than that of B: of course as much greater as the velocity of A is than that of B, of so much less weight must A be, to balance the larger weight B with a less velocity. If the lever be divided into twenty-eight parts, of which F A is twenty, and B F eight, then a weight of two pounds at A, will balance a weight of five pounds at B, because the weights and velocities taken on each side the fulcrum, and multiplied together, balance each other as $2 \times 20 = 5 \times 8$.

If, instead of the weights W and P, the end B of the lever, fig. 1, be put under a stone, log of wood, &c. and a man pull or press down the point A, he can, with an exertion equal to two pounds, or two hundred weight, raise a weight of five pounds, or five hundred weight. By a lever of this kind, the advantage gained is in proportion as the part A F is longer than F B; if the proportion be as fifty or eighty to one, a man may move a block of stone fifty or eighty times heavier than he could by his main strength only. To this kind of lever may be reduced all kinds of crows, scissars, pincers, candle-snuffers, and other instruments of this sort, which are compounded of two levers of the first kind.

2. A lever is said to be of the second kind, when the weight W is between the fulcrum F, and the power P, as in fig. 3. In this case, the weight and power balance each other, or the lever is in equilibrium, when the power is in proportion to the weight, as the distance of the weight from the fulcrum is to the distance of the power from it, or when $P : W :: FA : Aa$. To this sort of lever are referred doors turning on hinges, oars, and such kinds of knives as are

used by turners, patten-makers, &c. which are fixed at one end, thereby forming a fulcrum, while the other end is moved by the hand, or power; and the body to be cut, or the resistance to be overcome, is the weight. With respect to an oar, the blade acting against the water is the fulcrum, the boat to be moved is the weight, and the power is the hand acting at the other end of the oar. A pair of bellows consists of two levers of this kind. The fulcrum, or centre of motion, is where the ends of the boards are fixed near the pipe, the power is applied at the handles, and the resistance of the air acting against the middle of the boards, may be considered as the weight. The rudder of a vessel acts in the same way as an oar.

The principle of this lever shews the reason why two men, carrying a burden on a long pole between them, bear shares of the load which are to one another in the inverse proportion of their distance from it; for, if the weight be removed to the centre of the lever x, then a person at F, and another at a, would bear equal weights; but, if the pole be nine feet long, and the burden of a hundred and eighty pounds, be put at the distance of four feet from one end, and five feet from the other, the man at the short end will bear a hundred pounds, and the other man only eighty pounds. The same principle is applicable to the case of two horses of unequal strength, which may be so yoked to the carriage, that each horse shall draw a weight exactly proportional to his strength; this is done by so dividing the beam, that the point of *traction* may be as much nearer to the stronger horse than to the weaker, as the strength of the former exceeds that of the latter.

3. A lever is of the third kind, when the power P, fig. 4, is between the weight W, and the fulcrum F. In this kind of lever, the power and weight balance each other, when the power is in proportion to the weight, as the distance of the weight from the prop is to the distance of the power from it; that is, when P : W : : G F : g F.

To this sort of lever are generally referred the bones of a man's arm; for when he lifts a weight by the hand, the muscle that exerts its force to raise that weight, is fixed to the bone about one tenth part as far below the elbow as the hand is; and the elbow being the centre round which the lower part of the arm turns, the muscle must therefore exert a force ten times as great as the weight that is raised. This lever is never used where power is required to be gained; for in it the intensity of the power applied, must always exceed the intensity of the weight to be raised, or resistance to be overcome. The wheels of clocks and watches act upon the principle of a lever of the third kind.

In making experiments on the mechanic powers, we must take care that the instruments used are perfectly balanced among themselves, before the weights and powers are applied. Thus the bar used in making experiments on levers, should have the short arm so much thicker than the long one, as will be sufficient to balance it on the prop.

The balance, an instrument of extensive use in comparing the weights of bodies, is a lever of the first kind, whose arms are of equal length. The statera, or Roman steel-yard, is likewise a lever of the first kind, and is used for finding the weights of different bodies by a single weight, placed at different distances from the centre of motion D, fig. 5; for the shorter arm D G, exactly counterpoises the longer arm D X, which is divided into as many parts as it will contain, each equal to D G; the single weight P, suppose one pound, will serve for weighing any thing as heavy as itself, or as many times heavier as there are divisions in the arm D X: which divisions are divided into halves, quarters, &c. for the convenience of being accurate to those divisions of a pound.

The *Wheel and Axle.* In this mechanical power, the power is applied to the wheel, and the weight drawn up by a rope winding round an axle, of course the velocity of the power is to that of the weight as the circumference of the wheel is to the circumference of the axle, and the advantage

gained is in this proportion; but the circumferences of circles are to one another in the same proportion as their radii. Thus, in fig. 6, the centre of the axis and that of the wheel, which is the same point, is the centre of motion, the radius of the wheel is the distance of the power acting at the circumference of the wheel, from that point; and the radius of the axle is the distance of the weight from the same point. Hence the effect of the power is as the radius of the wheel $o\,x$; and the effect of the weight is as the radius of the axle $o\,z$; so that the two will be in equilibrio, or balance each other when $P : W :: oz : ox$. In fig. 7, we see in what way the wheel and axle is reduced to practice: A B is a wheel, and C D the axis; they move together, and it is evident that the power applied to the spokes *a, b, c, d,* &c. will move through as much more space as the bucket W, in proportion as the circumference of the circle, made by the spokes *a, b, c, d,* is larger than the circumference of the axle. To this kind of machine, made in a thousand different ways, belong all sorts of cranes for raising great weights, capstans, windlasses, &c.; but one of the safest and best cranes is that made by Mr. James White, a most ingenious mechanic at Gosport, of which there is a full description in the tenth volume of the Transactions of the Society for the Encouragement of Arts, &c.

In calculating the power gained by the wheel and axis, the thickness of the rope, and also the number of coils, when they run over or upon each other, must be taken into consideration, which is done by adding half the rope's thickness to the radius of the axle; or when there are several coils, over one another, as many times the thickness as there are coils wanting one half of one. It may be farther observed, that if the rope, chain, &c. be successively applied to wheels whose diameters continually increase, the axis will be turned with more and more ease, unless at the same time, the intensity of the power be diminished in the same proportion, and if this be the case, the axis will always be drawn with the same degree of force by a power continually diminishing. Of this

principle, watchmakers take advantage; for in their machines, the fusee on which the chain is wound, is so contrived as to present to the chain a series of wheels continually increasing in magnitude, so that in the case where the spring is strongest in its action, that is, immediately after it is wound, it draws the fusee by its smallest wheel, and as it unbends and becomes weaker it draws at the larger wheels; so that the motion of the watch-work, which depends upon a spring continually diminishing in strength, is always equable.

The *Pulley* is a small wheel turning on an axis, with a rope passing over it. Pullies, though varied in their construction, may be reduced to two kinds, viz. those that are *fixed*, and those that are *moveable*, or which rise and fall with the weight. A fixed pulley, as that shewn in fig. 8, serves only to change the direction of the power, and gives no mechanical advantage whatever; but when, besides the upper pullies, which turn round in a fixed frame or block, there is a block of pullies moving equally fast with the weight, the velocity of the weight is to the velocity of the power, as one, to twice the number of pullies in the lower or moveable block; and the power and weight balance each other, when the power is to the weight as one to twice the number of pullies in the moveable block: or in fig. 9, as P : W :: 1 :: 4. Another kind of pulley is represented in fig. 11.

In comparing the pulley to the lever with respect to the advantage gained, the fulcrum, fig. 10, must be considered as at A, the weight acts at *c*, placed between the fulcrum, and power P, acting at D. The power therefore being twice as far from the fulcrum as the weight is, the proportion between the power and the weight, in order to balance one another, must be as two to one. The same thing may be proved differently. Every moveable pulley, A D, hangs by two ropes, equally stretched, and of course which bear equal parts of the weight; but the rope, A B, being made fast at B, half the weight is sustained by it; and the other half of the rope, to which the power is applied, has but half the weight to sup-

port; consequently the advantage gained by this pulley is as two to one. One considerable advantage in the pulley is, that the direction of the acting power may be easily changed: thus a heavy weight on the ground may be raised to the top of a high building, by a person standing on the ground, and vice versa; and by a change in the direction of the acting power, we are able to employ the power to the greatest advantage. A horse for instance cannot draw in a vertical direction, but draws with all his advantage in an horizontal one: changing therefore, the direction, O P, by lengthening the rope, and having a fixed pulley at *n*, he becomes qualified to raise a weight W from any depth, by moving in the direction *n p*. In solid block pullies, fig. 12, invented by Mr. James White, the several grooves in the lower block are calculated as different pullies, and the advantage gained is in the same proportion.

It may be farther observed, that the space passed through by the power, in the case of a single moveable pulley, as fig. 10, is double the space that the weight passes through: in the case of two moveable pulleys it is four times, and so on; and as the velocities are as the spaces passed through, the momenta of the power and weight, will in the cases above described, be equal; that is, when they balance one another.

On an *inclined plane*, another of the mechanical powers, a weight raised or lowered, or a resistance overcome, moves only through a space equal to the height of that machine, in the time that a power impels it through a space equal to its whole length. Let A B, fig. 13, be a plane parallel to the horizon, and A D a plane inclined to it; and suppose the whole length, A D, to be three times as great as the perpendicular D B, in which case, the cylinder E will be supported upon the plane D A, by a power equal to a third part of the weight of the cylinder, for in this case P:W::DB:AD. This mechanical power is of great use in rolling up heavy bodies, as casks, wheel-barrows, &c. and to it may be reduced hatchets, chissels, and other edged tools, that are chamferred off on one side only.

A *wedge*, in the common form, is made up of two inclined planes, joined together at their bases, and the thickness of these planes makes the back of the wedge, to which the power of the hammer or mallet is applied in cleaving of wood: now there will be an equilibrium between the power impelling the wedge downward, and the resistance of the wood, or other substance acting against its sides, when the thickness, D G, fig. 14, of the wedge, is to the length of the two sides B F and D O, or as half the thickness D E of the wedge, at its back, is to the length of one of its sides, so is the power to the resistance: or in this case P : W :: B E : B F. The wedge is a very great mechanical power, since not only wood, but even rocks can be split with it, which could not be effected by any of the other mechanical powers.

The sixth and last mechanical power is the *screw*, which cannot be properly called a simple machine, because it is never used without a winch to assist in turning it, and it becomes a compound engine of very great force, either in pressing the parts of bodies closer together, or in raising weights. It may be conceived to be formed by cutting a piece of paper, fig. 15, into the form of an inclined plane, A B C, and then wrapping it round a cylinder: the edge of the paper, A B, will form a spiral line round the cylinder, which gives the thread of the screw, see fig. 16.

It is evident that the winch must turn the cylinder once round before the weight, or resistance can be moved from one spiral to another, as from *d* to *c*, therefore as much as the circumference of a circle described by the handle of the winch is greater than the interval or distance between the spirals, so much is the force of the screw. If the spirals be only at the distance of a quarter of an inch from one another, and the length of the winch be twelve inches, the circle described by the winch will be seventy-six inches nearly, or three hundred and four quarter inches, consequently three hundred and four times as great as the distance between the spirals, therefore a power at the handle of 1lb. will balance

more than 300lbs. acting against the screw. Hence it follows, that the longer the winch is, and the nearer the spirals are to one another, so much the greater is the force of the screw.

After the simple mechanical powers have been described, and their several properties investigated and understood, the pupil will advance to the consideration of compound machines, bearing in his mind when he comes to calculate the effects which they are intended to produce, that there will always be an equilibrium when the sum of the several powers is to the weight, as the sum of the velocities of the weight is to the sum of the velocities of the powers. And he will farther bear it in his mind, that though in the theory of the mechanical powers, all planes and other bodies are supposed to be perfectly smooth, levers to have no weight, cords to be perfectly pliable, and that there is no friction to be overcome; yet in practice all these things are to enter into the consideration, and in almost every compound machine, a full third additional power, must be allowed for moving and working a machine more than what is required to keep it in a state of equilibrium.

On the subject of friction, Mr., now Dr. Vince, has given, in vol. 75 of the Phil. Trans., a number of accurate experiments, of which the object was to determine: 1. Whether friction be an uniformly retarding force. 2. The quantity of friction. 3. Whether the friction varies in proportion to the pressure or weight; and 4. Whether the friction be the same on whichsoever of its surfaces a body moves.

In connexion with the subject of mechanics, a person will be led to consider the communication of motion, by direct and oblique impact: in the investigation of the centres of Percussion, Gyration, and Oscillation, his interest will be excited, and if entered into deeply, his mathematical skill will be tried. He will perhaps make himself acquainted with the different kinds of mill-work, which is of great importance in every large manufacturing country; and with the structure of clocks, watches, and other curious machines, which always increase in

number and complexity in proportion to the wealth and civilization of a state. Indeed these sorts of articles are, with respect to wealth, the cause and the effect. The student in mechanics being conversant with the elements of Conic Sections, will apply his knowledge to the investigation of the motions and paths of Projectiles, and of Central Forces. He will also be led to consider the properties and best mode of constructing different kinds of pendulums.

We shall reserve ourselves to the close of the department, Natural Philosophy, before we speak of those authors who have treated of the several subjects collectively, and only refer to a few who have given separate treatises on each distinct branch.

"An Introduction to Natural Philosophy," by John Keill, D. D. was published in Latin, was afterwards translated into English, and has gone through many editions in both languages. It contains the substance of Philosophical lectures read at the University of Oxford in the year 1700; and is well worthy of perusal, by those who can afford the time, without entirely neglecting some treatises of more modern date. The author's mode of demonstration is simple, but scientific, and in general it depends only upon the elements of geometry. Dr. Keill's first lecture shews the method of philosophizing: the next four treat of matter and its properties. The sixth lecture to the tenth inclusive, treats of *motion*, *time*, and *place*; in these, are descriptions and demonstrations of the properties of the mechanical powers. The laws of nature, and their application to the doctrine of percussion, are discussed in the four following lectures. The fifteenth and sixteenth lectures treat of the descent of heavy bodies on inclined planes; of the motion of pendulums; and of projectile forces. In several parts of these lectures the reader is supposed to be acquainted with Conic Sections, as well as common Geometry. And in a single instance his knowledge is required to extend to the doctrine of Fluxions. An appendix to the volume contains a demonstration of the Theorems of M. Huygens on the central forces. The title

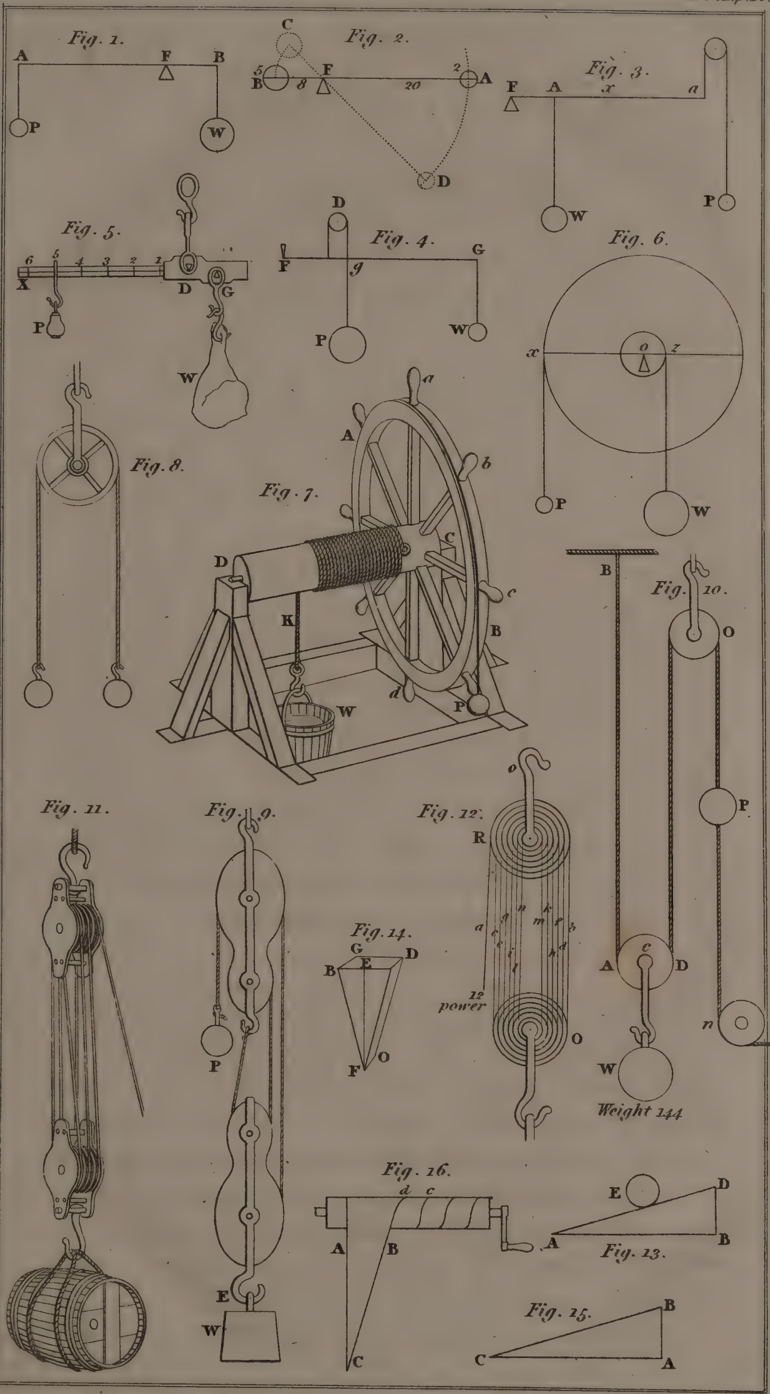
to the Latin edition of this volume is "Introductio ad Veram Physicam." Hence it is often denominated Keill's Physics.

A book very much used at Cambridge, among the junior classes, is entitled "The Principles of Mechanics, designed for the use of students in the University," by James Wood, B. D. It is divided into sections treating of matter and motion—of the laws, composition, and resolution of motion—of the mechanical powers, centre of gravity, and collision of bodies—of accelerated and retarded motion—of the oscillations of bodies and of projectiles.

A more elaborate work, the performance likewise of a lecturer at Cambridge, is entitled, "A System of Mechanics, being the substance of lectures upon that branch of Natural Philosophy," by the Rev. T. Parkinson, M. A. This System of Mechanics is introduced by a very good account of the doctrine of Ratios.

"The Principles of the Mechanical Powers" are briefly and ably stated, in a small tract by Dr. Hugh Hamilton, already referred to as author of a valuable treatise on Conic Sections. The tract now alluded to, is one of a small volume entitled "Philosophical Essays." It has passed through several editions, the third was printed in 1772.

"Select Mechanical Exercises: shewing how to construct different clocks, orreries, and sun-dials, on plain and easy principles. With several miscellaneous articles; and new tables: (1) For computing the time for any new or full moon. (2) For graduating and examining the usual lines on the sector, plain scale, and gunter. Illustrated with copper plates. To which is prefixed a short account of the life of the author. By James Ferguson, F. R. S." The title page of this work is sufficiently descriptive of its plan and object. The subjects discussed, will be found particularly interesting to those young persons who have a taste for practical mechanics. The biography of the author is simple, but calculated to awaken the best feelings in those for whose perusal it is evidently designed.



Lowry Sc.

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CHAP. II.

NATURAL PHILOSOPHY,

Continued.

HYDROSTATICS, history of—Fluid, definition of—Different branches of the science—Liquids, peculiarities of—Specific gravity—Gravity and pressure of fluids—Hydrostatical paradox—Lateral pressure—Rules for obtaining the specific gravities of bodies—Writers on Hydrostatics: Cotes—Vince—Parkinson. PNEUMATICS—of the atmosphere and its properties—Experiments of Galileo and Torricelli—The air-pump—Experiments. HYDRAULICS: Pumps—Fire-engines—Air-gun—Artificial fountains—Condensing-machine. ACOUSTICS—Nature of sound illustrated—Echo—Writers on Pneumatics, &c. Clare—Smeaton. STATICS—DYNAMICS—Writers: Gregory—Atwood—Wilkins.

WE trace the history of the science of Hydrostatics, and those which depend upon it, chiefly to Archimedes, whose discoveries were such as to do the highest honour to his genius and penetration. He was the inventor of the mode of measuring the bulk of solids, by immersing them in fluids. This discovery was thought by his contemporaries, and by many who succeeded him in the path of philosophy, to indicate a degree of ingenuity almost incredible. Archimedes himself valued it very highly, and was enabled to apply it to the determination of the specific gravity of Hiero's crown, and to the

detection of the fraud of the maker, who had returned a crown equal in weight to the gold that was given him, which he had adulterated with silver, supposing, that on account of its complicated form, it would be impossible to determine its bulk by calculation, and that, therefore, he must infallibly escape conviction. The invention of the hydrometer, which has generally been attributed to Hypatia, a learned Greek lady of Constantinople, has been also given to Archimedes, by some writers of authority.

The forcing pump, from which resulted the fire-engine, was invented by Ctesibius of Alexandria. He is also said to have been the inventor of the clepsydra, or water-clock; and of the air-gun, for throwing a ball to a great distance by the force of air. The ball was not then, as it now is, exposed immediately to the action of the air; but was impelled by the longer end of the lever, while the air acted on the shorter. Ctesibius was the son of a barber, and had his attention turned to mechanics, and the kindred sciences, by being employed to fit a shutter, with a counterpoise, sliding in a wooden pipe, for his father's shop-window.

Hero, a contemporary and scholar of Ctesibius, was the inventor of syphons, fountains, water-organs, and the fire-engine, the latter of which agrees in construction with that used at present: consisting of two barrels, that discharged the water alternately into an air-vessel. He described likewise an imperfect air-pump.

From this period little more was done in the science of hydraulics till the revival of letters. The Romans had water-mills in the time of Julius Cæsar. They had also their aqueducts, and water-pipes. In the middle ages, navigable canals began to be multiplied, first in China, and afterwards in other parts of the world. About the year 1600, Galileo made the important discovery of the effects, and weight and pressure of the atmosphere, in the operation of suction, and other phenomena. Before his time it was supposed that water was raised by a sucking pump, as it is called, on account of the impossibility

of the existence of a vacuum; if, however, a vacuum had been impossible in nature, the water would have followed the piston to all heights; but Galileo found that the height of its ascent was limited to about thirty-four feet, and inferred that the weight of a column of this height was the measure of the magnitude of the atmospherical pressure. Torricelli confirmed the theory, by shewing that a column of mercury was only supported when its weight was equal to that of a column of water, standing on the same base; hence the vacuum obtained by means of quicksilver, is frequently called the Torricellian vacuum. To the same philosopher we are indebted for the principle of spouting fluids, he having shewn that a quadruple height of a head of water was required, in order to produce a double velocity.

About the year 1654, Otto Von Guericke, of Magdeburg, constructed a machine similar to an air-pump, by inserting the barrel of a fire-engine into a cask of water; so that when the water was drawn out by the operation of the piston, the cavity of the cask remained nearly a void. And finding that the air rushed in between, or through the staves of the cask, he inclosed a smaller cask in a larger one, and made the vacuum in the internal one more complete, while the intervening space remained filled with water; still he found that the water was forced into the inner cask through the pores of the wood. He then procured a sphere of copper, two feet in diameter, and was exhausting it in the same way, when the pressure of the air crushed it with a loud noise. These were the beginnings of the air-pump, which the inventor lived to render much more complete; and he is said to have made all the principal experiments, which are now exhibited with that instrument. He also observed, that for very accurate experiments, the valve of the pump might be raised at each stroke by external force. An account of his many experiments was first published by Caspar Schott, and afterwards by himself, in his book, entitled "Experimenta nova Magdeburgica," printed at Amsterdam, in the year 1672.

In 1658, Hooke finished an air-pump for Mr. Boyle, in whose laboratory he was an assistant: this pump had two barrels, which was afterwards improved by Hauksbee, and remained in common use till the introduction of Smeaton's pump.

About this period the Marquis of Worcester invented a steam-engine; at least he threw out the hint by which others have been able to construct the machine, though it should seem from his own account, in the "Century of Inventions," that he had actually worked an engine himself.

Little was done in the way of practice with the Marquis of Worcester's ideas, till the year 1700, when Savary constructed engines on his plan; and, in ten years afterwards, the piston and cylinder were invented by Newcomen; these, with the invention of Beighton's apparatus for turning the cocks by its own motion, made the machine such as it remained nearly stationary for many years.

The commencement of the modern experimental improvements in hydraulics, has been dated from the investigations of Mr. Smeaton, respecting the effects of wind and water, an account of which was published in the Philosophical Transactions for 1759; and in 1769, Mr. Watt obtained a patent for his improvements of the steam-engine, which includes almost every essential change that has been made since the time of Beighton.

A fluid has been defined to be a body whose parts are put in motion one among another by any force impressed upon it; and which, when the impressed force is removed, restores itself to its former state.

Another definition is, that a fluid is a collection of material particles infinitely small, and moving freely on each other, in every direction, and without friction.

Fluids are divided into *elastic* and *non-elastic;* the former are those whose dimensions are diminished by increasing the pressure upon them, and increased by diminishing the said pressure; such are atmospheric air and the different gases.

The latter are those, whose dimensions are not, at least as to sense, affected by any increase of pressure; as water, oil, mercury, spirits, &c.

The science, which treats of the nature and properties of fluids, has been generally divided into three branches, viz. *Hydrostatics*, which comprises the doctrine of the equilibrium of non-elastic fluids; *Hydraulics*, which relates to the motion of those fluids; and *Pneumatics*, which treats on the properties of the different kinds of air. It is not unusual to include all these under the general term of Hydrostatics.

A fluid, which has no immediate tendency to expand when at liberty, is usually considered as a *liquid;* such are water, oil, and mercury: the atmospheric air, chemical gases, and steam, are fluids, but not liquids.

The *specific gravity* of a body is its weight, when compared with the weight of another body, whose magnitude is the same. And the *density* of a body is as the quantity of matter contained in a given space, and is, therefore, in proportion to its weight, when the magnitude is the same: accordingly the specific gravity of a body is in proportion to its density.

Example. A cubical inch of pure mercury is about 14 times heavier than the same quantity of water, of course the density and specific gravity of the former are 14 times greater than those of the latter.

The cause of fluidity is not perfectly known: some persons say that the particles of fluids are spherical, and accordingly touching only in points, have very little cohesion, and easily slide over each other. In reply to this, it is observed, that the particles of fluids are probably of the same nature or figure as those of solids, because they are perpetually changed into one another; as water into ice, and solid metals into liquids by heat. Among many modern philosophers, it is assumed, that a certain portion of heat, combined in some way or other with bodies, occasions fluidity; and that the relative proportions of heat contained in fluids and solids, is the cause of the difference between them.

Without, however, more particularly inquiring into the cause of fluidity, we shall proceed to notice the most remarkable properties of fluids, which are usually referred to in the science of hydrostatics.

It was formerly thought that fluids did not gravitate, *in proprio loco*, that is, had no weight when plunged in other portions of the like fluids; and Mr. Cotes, a most valuable writer, who was professor of experimental philosophy at Cambridge, about a century ago, took up a whole lecture to prove that water, and of course other fluids, do gravitate, or have weight in fluids. No one ever denied that fluids have weight in themselves, and the following experiment will prove satisfactorily that they have the same weight when immersed in another fluid.

Suspend from a balance an empty bottle, corked up, but so loaded with shot inside, or with lead cemented to the outside, as to sink; and counterpoise it by an equal weight in the opposite scale, when it is immersed in the water: then pull out the cork, so as to let the water rush in and fill the bottle, and the equilibrium will not only be destroyed, but it will require as much weight to restore the equilibrium, as the water in the bottle weighs.

One of the first laws that arrests our attention, is, that the surface of every gravitating fluid, when at rest, is horizontal. In the case of solids, the parts are so connected together, as to form but one and the same whole; and, as we have observed in mechanics, their weight may be considered as concentrated in a single point, called the centre of gravity. The case with fluids is very different: their parts gravitate independently of each other: hence the surface of a fluid contained in an open vessel, and at rest, is always level, or parallel to the horizon.

Fluids have this remarkable property, that they press not only in common with solids perpendicularly, but also upwards and sideways, in every direction. This is easily proved by an experiment. Take a glass tube of any length, open at both

ends, and stopping one end with the finger, let the other be immersed in water. The water will be prevented rising to any great height, by the air which is contained in it; but if the finger be taken away from the upper end, the air within the tube will escape, and the water in it will rise to a level with that in the vessel, being pressed upwards by the surrounding water. Hence it is inferred, that the pressure of a fluid on every portion of a vessel containing it, whether at the bottom, or on the sides, is equal to the weight of a column of the fluid, of which the base is equal to that portion, and the height to its depth below the surface of the fluid. Thus, if we have a vessel, in which the water is one foot deep, each square foot of the bottom, will sustain the pressure of a cubic foot of water, equal to about 1000 ounces avoirdupoise. The pressure of the water on a small portion of the lowest part of the side of the vessel containing it, is also equal to the weight supported by an equal portion of the bottom. We cannot, however, estimate the force sustained by any large portion of the side, without considering the different depths below the surface: thus, if a hole of an inch in diameter be bored at the bottom of a cask, and another of the same size close to the bottom, the water flowing from each will not be equal, because, though the pressure on the side, close to the bottom, is precisely equal to that on the bottom, yet it is not so at the distance of an inch above the bottom.

Again, if a fluid be conceived to be divided by an imaginary surface of any kind, the particles contiguous to it will be urged on both sides by equal forces; the fluid below pressing them upwards with as much force as the fluid above presses them downwards; for without this sort of equality of pressures, the fluid itself could not be at rest. If we employ a vessel A B C, Fig. 1. Plate II., of such a form, as that the parts x and z should occupy the place of any superior portion of the fluid, the pressure upwards against the parts x and z, thus substituted, will be precisely the same that would, in other circumstances, support the weight of the fluid made to occupy

the vacant spaces Ex and Dz; so that, as action and re-action are equal, though in contrary directions, the pressure on the bottom will be the same as if the parts x and z were removed, and the whole vessel EBCD were filled with water. Or if holes were bored at x and z, the pressure of the water upwards would cause it to ascend till the fluid was at a level in the three compartments of the vessel, with which there then would be a communication.

This leads to what has been denominated the hydrostatical paradox, which is of great importance in the science we are now explaining, viz. "That a quantity of fluid, however small, may be made to counterpoise any quantity however large." This principle is explained in various ways by different authors, but it will be sufficiently evident by remarking, that if to a vessel of any size, a bended tube be cemented to communicate with it, and rise up on the outside of the vessel, and water be poured into either of them, it will rise to, and stand at the same height in both, consequently there will be an equilibrium; and this will occur in all cases without regard to the shape of the vessels, nor does it at all signify whether the small tube stand parallel with the larger vessel, or whether it be inclined in any angle whatever. The general, and undeviating principle is, that water will find its level; hence this fluid, so important to mankind, may be carried, by means of pipes, to any distance, through valleys and over hills, provided those hills be not higher than the head whence it flows.

Another principle in hydrostatics is, that the pressure of a fluid is in proportion to its perpendicular height, and the base of the vessel containing it, without any regard to the quantity. Hence vessels have been burst, simply by fixing a small tube of considerable length in the top of them, and keeping them filled with water, because the pressure downwards, upwards, and sideways, is as great, as if the vessel itself was as high as the tube is long.

The pressure on each square inch of the side of a vessel, or on each square foot of the bank of a river or reservoir of

water, continually increases in descending to the bottom. The sum of the pressures on all the parts of the side is estimated by taking the mean depth, that is the point which would be the centre of gravity of the surface: thus, if we had a cubical vessel filled with water, or any other liquid, the centre of gravity of each side being the middle point, the pressure on each of the upright sides would be half as great as the pressure on the bottom, that is, since the pressure upon the bottom is equal to the weight of the water, and that on one side is equal to half the weight of the water in the vessel, of course the pressure upon the four sides and bottom is equal to three times the weight of the liquid.

If two fluids are of different specific gravities, that is, if equal bulks of them have different weights, their opposite pressures will counterbalance each other, when their heights above the common surface are inversely as their specific gravities; for the greater density of the one will precisely compensate for its deficiency in height. Thus a column of mercury standing at the height of thirty inches in a tube, will support the pressure of a column of water, in another branch of the tube, thirty-four feet high, because the weight of thirty inches of mercury is equal to that of four hundred and eight inches of water.

We shall now describe the method of obtaining the specific gravities of different bodies. The instrument, fig. 2, is called the hydrostatical balance; it does not differ very much from the common balance. To the beam, there are the two scale-pans adjusted, which may be taken off at pleasure. There is likewise another pan at *x*, of equal weight with that at *z*, furnished with shorter strings, and a small hook, so that any body may be hung to it, and then immersed in a vessel of water, CD.

The water used in this business should be quite pure, and of the same degree of temperature, because the density of water differs according to the degree of its temperature, hot water being somewhat lighter than cold. In very accurate experi-

ments the water should be distilled, and its temperature be ascertained by the thermometer. The general rule for finding the specific gravity of a solid, heavier than water, as a piece of metal, is this: "Weigh the body first in air, in the usual way, then weigh it when it is plunged in water, and observe how much it loses of its weight in this fluid, and dividing the former weight by the loss sustained, the quotient is the specific gravity of the body, compared with that of water." As an example, it is usual to take a guinea, which weighs in air 129 grains, and when suspended by means of a fine horse-hair, and immersed in water, it is found to balance $121\frac{3}{4}$ grains, losing of its weight $7\frac{1}{4}$ grains; now 129 divided by $7\frac{1}{4}$, or by decimals $\frac{129}{7.25}$, gives about 17 for the quotient, that is, the specific gravity of a guinea compared with that of water, is as about 17 to 1. Now it is known that a cubical foot of pure water, in all parts of the world, weighs 1000 ounces avoirdupoise, of course a cubical foot of such gold as guineas are made of, would weigh 17,000 ounces; by this method the specific gravity of all solids heavier than water is ascertained. Hence lead is found to be more than eleven times the weight of water, silver about ten times, copper and iron between seven and eight times, and so of other bodies. The reason of the above-mentioned rule is, that every body, when immersed in water, loses as much weight as is equal to the weight of a bulk of water of the same magnitude, that is, a quantity of water equal in bulk to a guinea would be found to weigh $7\frac{1}{4}$ grains. The same principle is universal. Hence we see the reason why boats or other vessels float on water: they sink just so low, that the weight of the vessel, with its contents, is equal to the quantity of water which it displaces.

It is not necessary to give the rules for obtaining the specific gravities of bodies lighter than water, or of fluids; they are described, with examples, in several of the books to which we shall refer, and in some of them are given tables of the specific gravities of almost all kinds of bodies. In these works also will be found accurate descriptions of divers instruments to

illustrate the principles of hydrostatics: such is the hydrostatic bellows; instruments to shew the laws of the lateral and upper pressures, and of spouting-fluids; the hydrometer, and the syphon used by distillers, the diver's bell, pumps, forcing and fire-engines, &c. are all explained in works treating on hydrostatics, unless by those writers who give separate treatises on hydrostatics and hydraulics: in these cases, it is understood that to hydraulics belong not only the conducting and raising of water, with the construction of engines for those purposes, but also the laws of the motion of fluid bodies, the nature of springs, both intermitting and others, the course of rivers, currents, &c. While hydrostatics explain the equilibrium of fluids, or the gravitation of fluids at rest: upon destroying that equilibrium, motion ensues, and here hydraulics commence. Hydraulics therefore suppose hydrostatics, and the generality of writers usually treat on both subjects in the same work.

The writers we shall refer to, independently of those who treat on every branch of natural philosophy in conjunction, are as follow:

"Hydrostatical and Pneumatical Lectures, by Roger Cotes, A. M." This work was published after the death of the author, by Dr. Smith; it possesses great merit, and will, so long as science lasts, be esteemed very highly by its votaries. The early death of Mr. Cotes, at the age of thirty-three, was deplored by mathematicians as a public calamity. Sir Isaac Newton asserted that, had his life been spared, he would have proved one of the greatest men that ever lived. "If Mr. Cotes had lived," said this illustrious philosopher, "we should have known something."

"The Principles of Hydrostatics, for the Use of the Students in the University of Cambridge, by the Rev. Dr. Vince," includes the fundamental principles of Pneumatics and Acoustics; and independently of the instruments illustrative of hydrostatics, he has given full descriptions of the air-pump and condenser; the thermometer, hygrometer, and pyrometer. There

is also a section devoted to the subjects of winds, vapours, and the formation of springs.

The same subjects are treated of more at large by the Rev. T. Parkinson, in a quarto volume entitled "A System of Hydrostatics." This is now generally bound up with the System of Mechanics by the same author, to which we have before referred. Both works are illustrated with numerous engravings; and with a map of the winds, shewing their currents, and in what parts of the world the monsoons, the variable and the shifting winds are to be met with, and in what months they prevail. Another valuable plate gives the graduations of fifteen different thermometers, by which the calculations of different authors to the boiling point may be easily reduced to one another. The last chapter in the volume treats in a concise but luminous manner of the motion of bodies in fluids.

PNEUMATICS.

The science of pneumatics treats of the mechanical properties of the air, or æriform fluids; such as their weight, density, compressibility and elasticity.

The air is a ponderous fluid, in which we live and breathe; and which entirely envelopes the whole globe, extending to the height of from 40 to 50 miles above it on all sides. That it is a fluid body is evident, because all its parts are easily moved, and yield to the smallest inequality of pressure:—that it has gravity is proved from the following considerations. 1. It always accompanies the earth in its path round the sun, which indicates that it is connected with the earth by the general force of gravity. On this account it is continually moving round the earth; forming, in some parts where it is quite free, the trade-winds. 2. It is owing to its gravity that it supports clouds and vapours, which are constantly floating in it. We see occasionally balloons, to which substances of many hundred weight are attached, float, and even rise some miles in height in the air; which proves the gravity of air, in the same manner,

that floating bodies in water prove the weight of the water which supports them. As the water must be heavier than the wood that floats upon it, so the air must be heavier than the smoke and vapours, and other substances that rise in it.

Besides this sort of reasoning, we have the most positive proofs on the subject, deduced from facts very familiar to the observation and apprehension of every person in common life If we close up the valve-part and nozzle of a pair of bellows, after having brought the boards together and forced all the air out, it will be found that a great force, equal to some hundred pounds, will be required to separate them, because they are kept together by the pressure of the external air which surrounds them.

If the air, by means of an air-pump, be taken from a glass flask, made with a valve for the purpose, and if the flask be accurately weighed, it will be found that it weighs, if it be a quart vessel, 15 or 16 grains less when it is exhausted, than when it is, as all vessels usually are, full of air, though in common language we say such vessels are empty. Hence it is found that a cubical foot of air weighs about an ounce and a quarter. By this means we obtain the specific gravity of air, compared with water, the usual standard; for if a cubical foot of water weigh 1000 ounces avoirdupoise, and the same quantity of air weigh $1\frac{1}{4}$ ounce; the former divided by the latter gives the superior weight of water above that of air, thus if 1000 ounces be divided by $1\frac{1}{4}$, or in decimals by 1.25, we gain as the quotient 800, shewing that water is about 800 times heavier than air at the temperature of 60°.

If a glass tube, 32 inches or more in length, be closed at one end, then filled with mercury, and inverted and plunged into a vessel of the same fluid substance, the mercury will remain suspended in the tube, descending to some point between 28 and $31\frac{1}{2}$ inches, according as the atmosphere is less or more dense; now it is manifest, that the suspension of the mercury is occasioned by the pressure of the external air upon the surface of the mercury; since if this pressure be taken away, by

placing the tube and the vessel under the receiver, and exhausting the air, by means of an air pump, the mercury will sink in the tube, and upon re-admitting the air, it will instantly rise as high as it was before, which is an experimental demonstration of the weight, gravity, and pressure of the atmospheric air. This is called the Torricellian experiment, from the person who invented it; and upon this depend the structure and use of the common barometer, because upon the weight of the air, which is perpetually varying, the mercury rises and falls, indicating the probability of certain changes in the atmosphere.

The same thing may be shewn in another way: instead of using a tube closed at one end, that is, hermetically sealed, as it is called, let it be open at both ends, but the upper part be accurately closed with a piece of bladder or parchment, the mercury will be suspended as before, and remain at the usual height; but if the covering be pierced with a needle, so as to admit the air, the mercury will immediately fall; for in this case the weight of the air presses upon the mercury in the tube, and there being now as much pressure on the mercury in the tube, as on that on the vessel outside the tube, there can be no equilibrium, until the fluid find its level.

Having established the gravity of the air, by which it is similar to all other terrestrial substances, we shall now point out the circumstances in which it differs from them, and from other fluids in particular; these are as follow.

1. The pressure of the atmosphere varies at different altitudes above the surface of the earth. As all the parts of the air gravitate, or press upon each other, it is easy to conceive, that those parts next the surface of the earth are more compressed, and of course denser than what those are at some height above it; in the same manner as if fleeces of wool were thrown upon one another to a great height, the fleeces towards the bottom, having all the weight of what is above them, would be squeezed into a less compass than those at, or near the top. Such is the case with the atmosphere, that

surrounds the earth. On the top of high hills, or lofty mountains, the air is found to be of considerable less density than that at or near the level of the sea. The precise altitude of the atmosphere has never been ascertained: it may extend to an immense distance, becoming rarer, in proportion to its distance from the earth. But as it is known that it does not refract the rays of the sun at a greater height than about forty-five miles, this therefore is usually considered as the limit of the atmosphere. It has been demonstrated by Mr. Cotes, that if the altitudes in the air be taken in arithmetical proportion, its rarity will be in geometrical proportion: thus at the altitude of

7	miles, the air is 4	times rarer than at the surface of the earth:
14	16	
21	64	
28	256	
35	1,024	
42	4,096	
49	16,384	

So that at forty-nine miles above the surface of the earth, the air is more than sixteen thousand times rarer than at the surface. But at the surface, a quart of air weighs but about fifteen or sixteen grains, of course at the height of forty-nine miles, it can weigh but the sixteen thousandth part of a grain.

2. Air is elastic, or capable of compression and expansion. This is proved by the following experiments, which will be better understood, when the structure and use of the air-pump have been explained. 1. By the great expansion of a small quantity of air in a bladder nearly empty, when the air is removed from the external parts under the receiver of an air-pump. 2. By the extrusion of a fluid from a glass bubble, by the expansion of a quantity of air contained in it. 3. By the expulsion of the white and yolk of an egg, through a small hole in the little

end, by the expansion of the air contained in the greater end. 4. By putting an almost emptied bladder into a small box, and laying a proper weight on the lid, which, on exhausting the air, will be raised up by the expansion of the air in the bladder. 5. Also a bladder filled with air, and just made to sink with a weight, will upon exhaustion, soon rise by the expansion of the contained air. 6. Glass bubbles, and images filled with water, so as to make them just sink in that fluid, will, on exhausting the air from the surface, rise to the top of the vessel. 7. Beer, cyder, water, and porous bodies, emit great quantities of air under the exhausted receiver. 8. A shrivelled apple, when put under an exhausted receiver, will have its coat distended by the internal air, so as to look smooth. 9. If the open end of a tube, whose other end is closed, be immersed perpendicularly in water, the space occupied by the air will be diminished, as the depth of the tube, or the upward pressure of the water is increased: or, if the shorter leg of a bent tube be closed, and mercury poured into the longer, the air will be compressed in the shorter leg into a space continually decreasing as the quantity of pressing mercury is increased; and if some of the mercury be taken from the longer leg, the air in the shorter will expand and occupy a proportionably larger space. 10. The mercury may be raised by the expansion of a small quantity of confined air to the same height in an exhausted tube above the air-pump, as that to which it is raised in the mercurial gauge, by the pressure of the atmosphere below it.

The limits of the condensation and rarefaction of the air have not been ascertained. Dr. Hales contrived to condense a portion of air into the fifteen hundredth part of its usual bulk, which is, perhaps, the greatest degree of condensation that has been ascertained with experimental precision; but it has often been carried to the thousandth degree, and in this case, air is as heavy as, or heavier than, water, though it still maintained its æriform shape, so that it cannot be, as some

have supposed only water in a different form, because being as dense or denser than water, it still retains its expansive powers.

3. The elastic force of the air is equal to the force of compression. For if the air be exhausted from an open tube, whose lower part is immersed in a vessel of mercury, which is subject to the pressure of air that cannot escape; then will this air, pressing upon the surface of the mercury, force it nearly to the same height, as it would have been raised by the pressure of the atmosphere. Besides, if the force with which the air endeavours to expand itself, when it is compressed, were less than the compressing force, it would yield still farther to that force; if it were greater, it would not have yielded so far: of course when any force has so compressed the air, that it remains at rest, the force of the air arising from its elasticity, can neither be greater nor less than the compressing force, but must be equal to it.

4. Heat increases the elasticity of the air, and cold diminishes it; or, which is the same thing, heat expands, cold condenses the air. This property is usually demonstrated by the following experiments: (1) Tie a bladder very close, having in it a small quantity of air, but so that the bladder is flaccid: lay it in this state before the fire, and as it becomes warm, the bladder is gradually distended, till at length it will burst. But if the bladder be removed into a cold place it will contract, and become as flaccid as ever.

(2.) If a glass, with air in it, be inverted in water, and then heated, the air in the upper part will expand, till it fill the glass, and expel the water out of it; and part of the air itself will follow, if the heat be continued and increased.

Galileo, as we have seen, was the first who discovered that it was impossible to raise water higher than about thirty-four feet, by what was at that time thought to be suction only; and thence he concluded, that it was not suction, but the pressure of the atmosphere, which was the cause of the ascent of water in pumps. By the same pressure mercury is suspended in a

tube to the height of between twenty-eight and thirty-one inches, according as the air is less or more dense.

After it had been discovered that the column of mercury varied in height, and consequently that the pressure of the air was different, at different times, and that the changes in the height of the mercury were accompanied, or quickly followed by alterations in the weather, instruments were manufactured for noting the changes in the atmosphere, which were called *weather-glasses;* and from their measuring also the *weight* of a column of the surrounding air, they were denominated, *barometers.* These instruments, however varied in their external appearance and structure, are nothing more than tubes, of 33 or 34 inches long, filled with, and inverted in cups of mercury, from which the air is expelled by boiling in the tubes: a scale, to note the risings and fallings of the mercury in the tube, is added.

Experiments of different kinds succeeded each other, and it was soon found that a column of mercury 29½ inches in length, and standing on a base measuring a square inch, weighs 15 pounds; consequently, that the air presses with a weight equal to 15 pounds, sometimes more, and sometimes less, upon every square inch of the earth's surface; and as there are 144 square inches in a square foot, the pressure upon each square foot is equal to 2160 pounds. As the air, like other fluids, presses in every direction, and as the surface of the body of a middle sized man measures about 14 feet, he must sustain every instant of time, a pressure equal to about $2,160 \times 14 = 30,240$ lb. or 27 cwt. avoirdupoise. This sort of pressure, which seems almost inconceivable to common apprehension, is supported by its equality on every part, and by the elastic force of the internal parts of the body, which balances the pressure that is made from without. But the pressure of the air may be made very sensible to any person, by putting his hand close down upon a glass receiver, open at both ends, the upper end being two or three inches in diameter, and then causing the air to be exhausted from the receiver, by means of the air-pump:

the pain that he will feel from this simple experiment, would in a few seconds be insupportable. If instead of the hand, a moistened piece of bladder be closely tied on the receiver, and the air from under it be exhausted, the pressure of the incumbent atmosphere is seen by the bending in of the bladder, which becomes more and more concave, till at length it bursts with a report equal to that of the discharge of a pistol.

The last experiment leads us to explain the structure and use of the air-pump for experiments in this branch of science. Of this instrument we have the representation in Plate II. fig. 3. BB are two hollow brass barrels, each containing a piston to work up and down in them, with a valve opening upwards. The pistons are worked by means of the winch H, which has a concealed pinion that fits into the teeth of the racks CC; these are joined to the ends of the pistons, and by this means they are moved up and down alternately. On the frame DE, is fixed a brass plate G, ground perfectly flat; and in the same frame is inserted a brass tube communicating with the cylinders and the cock I, opening into the centre of the brass plate *a*. To exhaust or empty the glass receiver K of its air, it must be placed very accurately on the brass plate; and to make it fit more evenly, a strip of wet leather is often put under the edge, though, in some cases, it will be sufficient to rub the rim over with lard or soft pomatum. Having turned the cock I, to prevent the access of the surrounding air, the pistons are to be worked by means of the winch; and in a few turns, the receiver will be rendered immovable, until the cock I is turned back, when the external air will rush in with violence, and a considerable noise will be heard.

A copper Florence flask, containing a quart, may be made to be screwed on the brass plate at *a*; and having a valve at the mouth, it may be exhausted of its air. If weighed when full of air, and also when it is emptied as far as the air-pump can perform the operation, it will be found there will be a difference of about 16 grains; which proves that the quantity

of air contained in the flask, weighs 16 grains—this weight will be greater or less according to the state of the atmosphere.

The pressure of the atmosphere is most satisfactorily exhibited in the following experiment; it being first premised that when the surface of a fluid is exposed to the air, it is pressed by the weight of the atmosphere equally on every part, and consequently remains at rest; but if the pressure be removed from any particular part, the fluid must yield in that part, and be forced out of its situation. Under the receiver A, fig. 4. placed on the plate G of the air-pump, fig. 3. introduce a small vessel *z*, containing a certain portion of mercury; and through the collar B, suspend a glass tube *x*, open only at the lower end. By moving the wire BD up and down, the tube *x* may be plunged into the mercury, but it is contrived that no air can be admitted at B. If the receiver A be exhausted of its air, and the tube forced into the mercury, the fluid will not rise in it beyond its level; if now, by turning the cock I, the air be let into the receiver A, its pressure upon the surface of the quicksilver in *z*, will force it up into the tube, and continue to do so, until the weight of the elevated quicksilver in the tube, press as forcibly on that portion of it which lies beneath it, as the weight of the air does on every other portion without the tube, when there will be a perfect equilibrium.

Another experiment depending on similar principles, is this: Take a common syringe of any kind, and having pushed the piston to the farthest end, so as to force out all the air before it, immerse it into a vessel of water; then draw up the piston, and the water will follow it. A common squirt, used by children, will shew this experiment as well as any other kind of syringe. The reason of the thing is, that when the piston is pulled up, the air is drawn out of the syringe with the piston; and the pressure of the atmosphere being removed from that part of the water immediately under it, the water in that particular part is obliged to yield to the pressure on the surrounding surface. It is upon this principle, that all those pumps,

erroneously denominated sucking pumps, act. The piston, fitting tightly in the inside of the barrel, by being raised up, removes the pressure of the atmosphere from that part; and consequently the water follows the piston, by means of the pressure on the other parts of the surface.

HYDRAULICS.

The pump to which we have just alluded, is one of the most common and useful of hydraulic engines: there are three kinds, called by the workmen in that branch of business, the *sucking*, *lifting* and *forcing* pumps. By the last two, water may be raised to any height, with a proper apparatus, and requisite power; but by the sucking-pump, for reasons that have been already explained, it can be raised only 33 feet from the surface of the water, into which it is plunged; and in practice it is rarely applied to the raising of water more than from 25 to 28 feet, lest from the lightness of the atmosphere, its action should be impeded.

The common, or sucking pump as it is called, consists of a pipe open at both ends, see fig. 5, in which a moveable cylinder or piston works, by means of a handle not shewn in the figure. The piston C, is contrived, by leather, or other methods, to be air-tight, that is, not to admit the air to pass by the edge into the lower part of the pipe. In the piston there is a valve, *a*, opening upwards, to allow the air and water from below it to ascend, and at the same time prevent either from descending. The pipe AB, usually consists of two parts, of which the first AD, is called the barrel, and is larger than the lower DB, called the suction-pipe. At D there is fixed a valve *x*, opening upwards like that at *a*, and for the same purposes. The lower end of the suction-pipe B, is immersed in the water, which is admitted through small holes, to prevent the entrance of dirt; and at the upper part of the working barrel is a wide head A, and a spout E, for the exit of the water when it is raised.

The mode of its operation is as follows: The piston C, is

pushed down close upon the valve x, both valves remaining shut by their own weight. If the bucket C, be drawn up, a vacuum will be formed under it, of course the air in z will open the valve x, and fill the part between D and C, which had been exhausted; and as the quantity of air that was before in z, is now equally diffused through the whole space from B to C, it will be much rarer than it was before; and not being equivalent to the pressure of the air on the surface of the water w, the water will be forced up into the suction-pipe, as high as z, perhaps, until the air within be as dense as it was before, that is, till the pressure within the barrel is equivalent to that of the atmosphere without; and there it will remain, things being now in equilibrio. Upon depressing the piston a second time, the same effect is produced; and after three or four strokes, the water will be brought up into the head A, and be carried off by the pipe E. Now, by alternately raising and depressing the piston, the effect is produced, and the water continues flowing out; for every time the bucket is raised, the valve x rises, and the valve a falls; and at every time the piston is depressed, the valve a is raised, and x falls. This is the most useful pump in domestic affairs, and is seldom out of order when in continual use, being quite simple in its construction, and acting without any complicated machinery. If left to get dry, the leathers of the valves, and about the piston, are apt to shrink, so that the water will not follow it: in this case, water must be thrown in at E, to cause the leathers to swell, making them again air-tight, or fit close. This, in the country, is called fetching the water, as if one portion of fluid was sent down to bring the rest up.

The lifting-pump is shewn at fig. 6. It consists of a body or barrel AB, at the lower end of which is a valve a, opening upwards as before. In the barrel is a solid piston P, perforated, and having upon it a valve b, likewise opening upwards. This piston is moved up and down by a rod, worked with a handle or other means. The piston and the lower valve are supposed to be under the surface of the water

in the well; and when the piston is pushed down, the water below it not being able to go downwards, on account of the valve *a*, raises the valve in the piston, and gets above it; and when the piston is drawn up, it lifts all the water above it, while the pressure of the atmosphere causes more water to supply its place by raising the valve *a*. Thus by successive motions of the piston, the water is lifted to the top, and discharged into the head, whence it flows off by the spout. In this pump, the water raised is always equal to a column, whose base is equal to the top of the piston, and whose altitude is equal to the distance from the piston to the head. This kind of pump is much used in water-works, and like the last is very simple in its operation.

The forcing-pump is represented by fig. 7. It consists of a barrel A B, and a piston, or forcer C. There are likewise two fixed valves, one at D, and the other at S, so disposed, as to permit the water to rise freely, but to prevent its return. When the forcer is first moved upwards in the barrel, the air between that and the water below having room to dilate, by its natural spring, will be rarefied: the water will rise in AB, and after a few strokes, fill the cavity between E and S; and as it cannot escape downwards by the lower valve at D, it will by the pressure of the piston, or plunger, C, be forced through the valve at S; that valve, which shuts of itself, being so made that the water cannot return. By every fresh stroke, more water is raised and forced into the vessel WV. This vessel is closed at top, and made air-tight by the pipe T*t*, which reaches nearly to the bottom of the vessel. When the water rises in this vessel above T, the lower end of the pipe, the air which is above the water in the vessel, being now confined, will be condensed into a smaller space by the admission of more water, at each action of the piston; and pressing by its elasticity upon the surface of the water, which cannot return by the valve S, forces it up the pipe T, in a continued stream. The air vessel, must, in proportion to the other parts of the machine, be so large, that

the change of bulk of the compressed air, during the inaction of the piston, may be inconsiderable, otherwise its action on the water will not continue steady till the next stroke.

Fire-engines, air-guns, fountains, and many other instruments, derive their efficacy from the elasticity of condensed air. The following is a description of a common engine for extinguishing houses and other buildings, when on fire. It is composed of two barrels, in each of which a solid piston is worked by means of a double lever, one piston descending and the other ascending at the same time. These barrels are fixed in a vessel of water, with which they communicate by valves, opening into them; and they also communicate with a strong vessel, by means of pipes, terminated by valves opening into it. If either of the pistons be raised, the water rushes out of the receiver through the valve; and the piston, being now depressed, forces the water into the vessel connected with the pipe: by repeated strokes of the pistons, the water in that vessel condenses the air above it; the elasticity of which, by pressing upon the suface of the fluid, is sufficient to force it in a continued stream through a pipe of any length.

In an air-gun, just behind the ball, which is placed at the bottom of the barrel is a cavity, terminated at both ends by valves opening within it; and in the stock is a condenser or forcing syringe, by which air is forced into this cavity; and when it is sufficiently condensed by repeated strokes of the piston, the valve, next the ball, is opened by the trigger, and the force of the condensed air expels the ball with a velocity proportioned to the condensation of the air. Artificial fountains are constructed on this same principle. Suppose a vessel to be constructed like the part of the air-vessel, fig. 7, W *X Z n*, and the water filled up to T, so that the pipe T *t*, may dip a certain way into it. By means of a condensing machine, which will be immediately described, air is forced in through the pipe T *t*, into the water; but being lighter than that fluid, it will ascend into the part W T *n*; the quantity of air that may be thus thrown in, can only be limited by the strength of

the materials. When filled, and while the condensing syringe is removed from *t*, the stop cock *a*, may be turned to prevent the water from escaping till a proper *jet* is put on at *t*; when the cock *a*, may be again opened, and the water will rise to a great height, or may be made to pass in any form that shall be thought proper. If it is sent up in a perpendicular stream, it will be seen that its height is continually diminishing, because as the water flows out, the part *W*, is enlarged, and the air, occupying a larger space, is more rare, and the pressure is much diminished.

In fig. 8, we have a representation of a condensing machine: it consists of a brass barrel containing a piston, which has a valve opening downwards; so that as the piston is raised, the air passes through the valve; but as the piston is pushed down, the air cannot return, and is, therefore, forced through a valve at the bottom of the barrel, that allows it to pass into the receiver B, but prevents it from returning. Thus at every stroke of the piston, more air is thrown into the receiver, which is made of very thick and strong glass, and the receiver, is held down upon the plate C, by the cross-piece D, and the screws E and F. The air is let out of the receiver by means of the stop-cock constructed with a tube that runs to C.

If the clapper of a bell is made to strike in condensed air, the sound is much stronger than when it is struck in common air. A common glass phial exhausted of its air, and which would, from its curvature, bear the common pressure of the atmosphere will be broken to pieces by condensing the air round it.

ACOUSTICS.

When bodies move in elastic fluids, they condense that part towards which they move, at the same time the part from which they recede is rarefied. This condensation and rarefaction must produce an undulatory motion in the fluid: so that if a body, by percussion, be put into a tremulous motion,

every vibration of the body will excite a wave in the air, which will proceed in all directions. The sensation excited, by waves thus formed, and which enter the ear, and produce a like motion in a thin membrane stretched across the auditory passage is called *sound*. Hence it is assumed, that a sound is propagated from the sounding body, by the motion of the air. This proposition is thus proved: 1. The perception of sound, without the actual impulse of matter upon the organ of hearing, is impossible, and it must, therefore, be conveyed by some intermediate fluid. 2. The sound of a bell, included under a receiver, is weaker when the air is rarefied, and stronger when confined in condensed air. 3. A strong receiver, such as that represented in fig. 6, filled with common air, in which a bell was suspended, was fastened down in the way there represented, so that none of the included air could escape, and then covered over with a much larger receiver, and the air, contained between the two, exhausted; in this case the sound of the bell could not be heard, which proved that sound cannot be transmitted through a vacuum: the air being re-admitted between the receivers, the sound was heard. 4. That the motion is communicated by the sounding body to the contiguous air, is quite evident from the visible motion of small particles of dust floating in it; and in the vicinity of very loud sounds, as those produced by the discharge of artillery, the surface of any contiguous standing water is sensibly agitated, and even the glass in the neighbouring windows has been broken.

All sonorous bodies are elastic, which is proved by the following circumstances. 1. If glass, bells, &c. be covered with a little dust, their parts will, from the tremulous motion of the particles of the dust, appear to move when they are struck. 2. This motion is observed in water, or other fluids, contained in a glass vessel, when its edge is made to emit sound by friction. It is well known from experiment, and has been established by mathematical reasoning, that all sounds whatever arrive at the ear in equal times, from sounding bodies at equal

distances. The common velocity is at the rate of 1,142 English feet in a second of time: hence are easily ascertained the distances of ships, or other objects: thus, if a gun be fired from a ship in distress, and the report is heard at an interval of 5, 8, or 12 seconds after the flash is seen, as light, in such small distances, may be considered as instantaneous, the distance of the vessel may be considered at $5 \times 1,142$, or $8 \times 1,142$, or $12 \times 1,142$ feet from the observer.

When ærial waves meet with an obstacle which is hard, and of a regular surface, they are reflected; and consequently an ear placed in the course of those reflected waves, will perceive a sound similar to the original sound; but which will appear to proceed from a body situated at the same distance behind the plane of reflection, as the real sounding body is before it. This reflected sound is called an *echo*. From this property of reflection, it is found that sounds uttered in one focus of an ellipse, are greatly magnified in the other focus; but though the loudest echo be produced when the sounding body is in one focus of an ellipse, and the hearer in the other, yet echoes will be heard in other situations, when a sufficient number of reflected pulses arrive at the ear to excite a distinct perception. A speaker may often hear the echo of his own voice, when the reflecting obstacles are properly situated. On this subject the following proposition has been given.

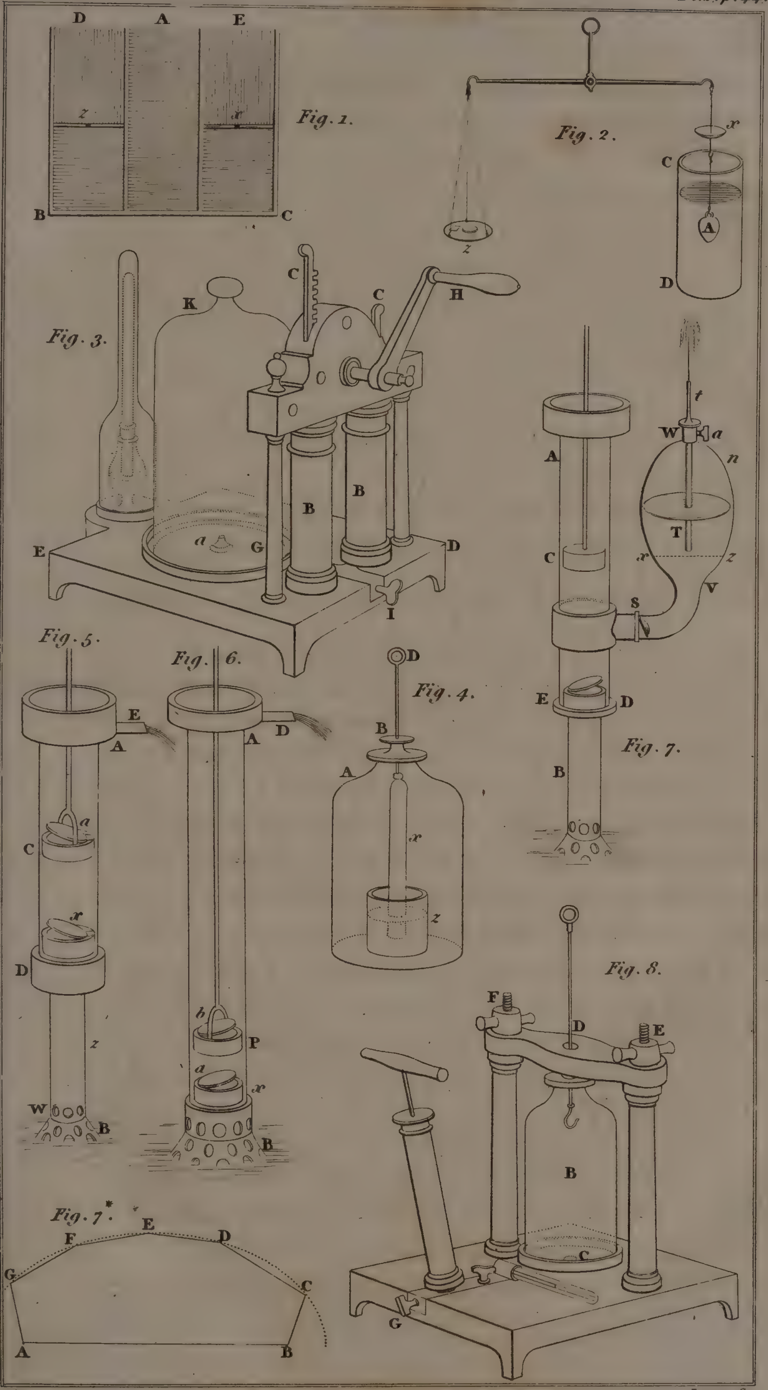
If the pulses of any sound, propagated from a sounding body, or centre, A, fig. 7, strike against a number of obstacles C, D, E, &c. and the sum of the lines drawn from A to each obstacle, and from each obstacle to a second point B be equal, an echo will be heard, provided the interval AB be about 127 feet less than AC+CB. For each of the obstacles C, D, E, F, &c. will be a new centre of pulses, and one series of each will pass through B; and since by the nature of an ellipse $\overline{AC+CB}$; $\overline{AD+DB}$; $\overline{AE+EB}$, &c. are all equal to each other, the pulses propagated from A to C, D, E, &c. and thence to B, will arrive there at the same time, and concur in producing a perception of sound. Now it is asserted by

Musschenbroek, that the ear of a well exercised musician can only distinguish such sounds as succeed each other about 9 times in a second of time, and consequently two sounds at a less interval than the ninth part of a second of time must coalesce and form one single sound. But sound, as we have seen, describes 1,142 feet in a second, therefore $\frac{1142}{9} = 127$ feet nearly, is the space it passes over in the ninth part of a second; and consequently if AB be less than AC+CB by 127 feet, two distinct sounds will be heard at B.

Again, the common rate of clear articulate speaking, is said to be at the rate of three syllables and a half in one second, or seven half syllables in a second; and as sound moves at the rate of 1,142 feet in a second, if the echo arrive at the ear of the speaker after 1, 2, 3, 4, &c. half syllables are pronounced, it is clear that the space described by it will be $\frac{1142}{7}$; $\frac{1142 \times 2}{7}$; $\frac{1142 \times 3}{7}$, and consequently the distance of the reflecting object will be half of this fraction.

In an elastic tube, one of whose orifices is very small, and the other very large, the sound of a human voice applied to the smaller orifice, will be augmented. For the lateral expansion of the air is diminished by the sides of the tube, and of course the direct expansion and velocity of the included air must be increased. Every point of the tube against which the air is impelled, has a tremulous motion, and becomes a new centre for propagating the pulses, which, striking against the ear at the same time, must be increased. Again, as the diameter of the tube perpetually increases, and the parts of it vibrate in directions perpendicular to the surface, the vibrations will partly conspire in impelling the particles forward, and thus increase their velocity, on which account the intensity of sound ought to be increased. Such seem to be the principal causes of the augmentation of sound in the speaking trumpet, and that figure for the instrument is to be preferred, in which their combined influence is the greatest.

Besides the works on Hydrostatics, Pneumatics, &c. which



Lowry Sc.

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have been already mentioned as elementary, we may notice the third and fourth volumes of the "Scientific Dialogues," which are adapted to students of the lowest form. Also "The motion of Fluids, natural and artificial, in particular that of the Air and Water, &c. by Martin Clare." This volume includes, like almost all others on the same subject, an illustration of the doctrines of Hydrostatics and Pneumatics: under the former, the nature and motion of fluids, as water, in pipes, pumps, syphons, fire-engines, water-works, &c. are explained in a very easy and familiar manner. In this part of the work, likewise, there are ample descriptions of several hydrostatical instruments, and explanations of the method of finding the specific gravities of all sorts of substances, whether solid or fluid. In the second part of the volume, the pressure and gravity of the air are exhibited by convincing and undeniable experiments. The barometer and the air-pump are particularly described, and we have some useful observations on the effects of the air's pressure,—on the art of diving,—and on various pneumatic instruments. Although this work has been published nearly fourscore years, it may be recommended, in connexion with the works of Vince and Parkinson, as a safe guide to students in these branches of science; who may again be directed to the first of Dr. Hamilton's Essays, referred to at the end of the article Mechanics, which contains a number of simple experiments, that may, for the most part, be easily repeated without much trouble or expense.

Mr. Smeaton's, "Experimental Inquiry concerning the natural Powers of Wind and Water to turn Mills, &c." published in 1794, contains much useful matter depending upon Mechanical and Hydraulic principles; such as (1) the result of twenty-seven sets of experiments upon the power of under-shot wheels, together with maxims and observations deduced from them: (2) a variety of experiments upon over-shot wheels, from which (taking for granted that the experiments of so able an engineer, as Mr. Smeaton, are quite accurate) it appears that the effect of over-shot wheels is double that of under-shot:

and (3) an account of windmill-sails, with experiments upon sails of different structures, positions and quantities of surface.

Hitherto, in treating of the topics connected with Natural Philosophy, we have referred to works, and to subjects that are merely elementary, such as will satisfy the tyro in his first steps; and having proceeded so far, he will scarcely stand in need of more particular directions, his knowledge now will be a sufficient guide to him in his abstruser inquiries, and he will ascend to the more general doctrines included by philosophers under the term *Statics*. Elementary treatises, generally speaking, are confined to the consideration of the equilibrium of bodies, and the circumstances necessary for producing it.

Every kind of work, which is to be performed by a machine, may be considered abstractedly, as a retarding force; the impulses of water and wind, which are employed as moving powers, act by means of pressures which they exert on the impelled point of the machine; and the machine itself may be considered as an assemblage of bodies moveable in certain limited circumstances, with determined directions and proportions of velocity. From these considerations, mechanicians have inferred an abstract condition of a body acted on by known powers. And they have found, says a writer on this subject, that, after all the conditions of equilibrium are satisfied, there remains a surplus of moving force. They can accordingly state the motion which will ensue, the new resistance which this will excite, the additional power which this will absorb; and they have, by a particular mode of reasoning, determined a new kind of equilibrium, not thought of by ancient writers on this subject, between the resistance to the machine performing work, and the moving power, which exactly balance each other, and is indicated, not by the rest, but by the uniform motion of the machine. In the same manner, mathematicians have been enabled to calculate that precise quantity of motion of water, which will balance the superiority of pressure, by which the fluid is forced through a sluice, a pipe, or a canal, with a

constant velocity. Thus the general doctrine of forces has come to be considered in two points of view, according as they balance each other in a state of rest or motion. These two ways of considering the same subject require different principles, and a different mode of reasoning. The first has been named *Statics*, as expressing that rest which is the test of this kind of equilibrium. The second has been denominated *Dynamics*, or Universal Mechanics, because the different kinds of motion are characteristic of the powers or forces which produce them. The science of statics, therefore, is preparatory to the study of mechanics in this enlarged view of it, and is the foundation of many useful parts of knowledge, which have been thus enumerated. 1. It comprehends the doctrine of the excitement and propagation of pressure, by which the energies of machines are produced. A pressure, for instance, is exerted on the impelled point of a machine, such as the float-boards or buckets of a mill-wheel. This excites a pressure at the pivots of its axle, which acts on the points of support: a pressure is also excited at the acting-tooth of the cog-wheel, on the same axle, by which it urges round another wheel, and so on to others, and by these means a pressure is ultimately excited in the working point of a machine. The science of statics teaches how to find the intensities and directions of all these pressures, and how much remains at the working point of the machine unbalanced by resistance. 2. It comprehends every circumstance which influences the stability of heavy bodies; the investigation and properties of the centre of gravity; the theory of the construction of arches, vaults, and domes; and the attitudes of animals. 3. The strength of materials, and the principles of construction, so as to make the proper adjustment of strength, to the supposed strain, in every part of the machine, &c. In practice, therefore, statics furnish what may be called a theory of carpentry, and affords instructions for framing floors, roofs, centres, &c. 4. This branch of science comprehends the whole doctrine of the pressure of fluids, whether liquid or æriform, whether arising

from their weight, or from any external action. Hence is derived a knowledge of the stability of ships, and their power of maintaining themselves in a steady and upright position, in opposition to the action of the wind on their sails. On these and other topics of the like kind, the reader may be referred to "A Treatise of Mechanics, Theoretical, Practical, and Descriptive, by Olinthus Gregory, LL. D." in 2 vols. 8vo. The *first* contains the theory of Statics, Dynamics, Hydrostatics, Hydrodynamics and Pneumatics; and the *second* contains Remarks on the Nature, Construction, and Simplification of Machinery; on Friction, the Rigidity of Cords, First Movers, &c. with descriptions of many curious and useful Machines. To this we shall add "A Treatise on Rectilinear Motion and the Rotation of Bodies, &c. By G. Atwood, F. R. S." which contains a variety of topics that will claim the attention of those who have advanced beyond the mere elements of this branch of science.

"Mathematical Magic, or the Wonders that may be performed by Mechanical Geometry, &c. by John Wilkins, late bishop of Chester."

The author of this entertaining work, informs us that the reason of the title, *Mathematical Magic*, was because the art of such mechanical inventions as he has described, had been usually attributed to the power of magic. The *first* book is entitled Archimedes, in honour of him, to whom is to be chiefly assigned the invention of the mechanical powers. The *second*, he styled *Dædalus*, after him, who is distinguished among the ancients for his skill in making *automata*, or self-moving engines, and for reducing to practice the mathematical principles of philosophy.

The enumeration of the various contents of these books would require a larger space of our work, than can be allowed to a single treatise; it will be sufficient to inform the reader that they are all interesting, and cannot fail to afford real entertainment to persons who have a taste for subjects of this kind.

CHAP. III.

NATURAL PHILOSOPHY,

Continued.

Optics, principles of—Nature of Light—Refraction of the rays of light—Reflexion of light—Different refrangibility of the rays of light—The Rainbow—Vision and structure of the Eye—Optical Instruments—Microscopes—Telescopes—Camera Obscura—Magic Lantern—Phantasmagoria—Writers on Optics.

THE science of Optics so important to the purposes of life, is a mixed mathematical science, which explains the manner in which vision is performed in the eye; it treats of sight in general; gives the reasons of the several modifications or alterations which the rays of light undergo in the eye; and shews why objects appear, under different circumstances, of different magnitudes, sometimes more distinct, sometimes confused, sometimes nearer, and sometimes more remote. In this signification the science of Optics is considered by Sir Isaac Newton. The history of the science has been detailed by the illustrious Priestley, in a large quarto volume, which has generally been considered as one of the most interesting of his numerous works. In a small compass, such as the nature of this work would admit, it would be scarcely possible to include even a sketch of the history, that would be intelligible. We

shall, therefore, proceed to explain some of the fundamental principles of the science, such as the nature of light, the laws of refraction and reflexion, the nature of vision, and the structure of some of the commoner and more useful instruments.

Of the Nature of Light. It is generally agreed, though the subject does not admit of demonstration, that light consists of inconceivably small particles, flowing with amazing velocity, in all directions, from the luminous or radiant body. This theory of light appears the most simple of any, and serves to explain all the phenomena of vision; and, therefore, has by the majority of writers on the subject, been assumed as true.

The velocity with which light moves, was first observed by M. Roemer, who ascertained that it travelled from the sun to the earth, a space of 95,000,000 of miles, in about eight minutes, that is at the rate of about 200,000 miles in a second of time. This fact was inferred from the following circumstance: the eclipses of Jupiter's satellites, happen sometimes sooner and sometimes later than the times given by the tables, according as the earth is nearer to, or farther from that planet. Thus, when the earth is at C, Pl. III. fig. 1, between the sun and Jupiter, his satellites are seen eclipsed about eight minutes sooner than they would be, according to the calculated time, which is given for the mean distance of the planet; but when the earth is in the opposite point of the orbit, D, these eclipses happen eight minutes later than the tables predict them. Hence then it was inferred that the motion of light is not instantaneous, but takes about sixteen minutes to pass over a space, equal to the diameter of the earth's orbit, which is about one hundred and ninety millions of miles in length. If, therefore, the sun were to be annihilated, we should see him, as we now see him, eight minutes after that event happened. Hence, it is easy to calculate, how long light is travelling to us from the moon, the other planets, and even from the fixed stars, if their distances could be ascertained. The distances of the latter are,

indeed, immensely great, so that from the nearest of them, suppose Sirius, the dog-star, light must take years even to travel to the earth; and it has been conjectured by some philosophers, that there are stars so remotely situated with respect to the solar system, that the light flowing from them, ever since the creation, and travelling at the rate of 200,000 miles per second, has not even yet reached the earth.

Since the velocity of light is so great, it is justly inferred, that its particles must be almost infinitely small, or the organs of vision would be destroyed by their impulse upon them. The velocity and minuteness of these particles are not more a matter of wonder, than the rarity of the fluid; for its rays cross each other in all possible directions, without the least apparent disturbance. Thus, we can see through a very small pin-hole, in a piece of paper, a variety of objects at the same time. Now the light proceeding from these objects must pass at the same instant through the hole, in a great variety of directions, before they arrive at the eye, yet the vision is not in the least disturbed by it.

Again, if a lighted candle be set, in a dark night, upon an eminence, it may be seen all around to the distance of half a mile; so that there is no place within the sphere of a mile in diameter, in which the eye can be placed, where it will not receive some rays from the flame of this candle.

Another circumstance respecting the rays of light is, that they move always in straight lines, as is evident by the impossibility of seeing through a crooked tube.

As light proceeds from a centre, its intensity decreases as the square of the distance from the luminous body increases; that is, at twice the distance from the luminous body, an object will be enlightened only one-fourth as much as it was before; and at three times the distance, only one-ninth as much, and so on.

By a *ray* of light is meant the motion of a single particle, and its motion is represented by a straight line.

Any parcel of rays proceeding from a point, is called a

pencil of rays. By a medium is meant any pellucid or transparent body, which suffers light to pass through it. Thus air, water, and glass are media.

Of Refraction. Where rays of light, after passing through one medium, on entering another medium of different density, are bent out of their former course, and change their direction, they are said to be *refracted.* Thus S *a*, (Fig. 1.* Plate III.) is a ray which, when it enters the medium A B, instead of proceeding in the same direction, *a n*, is made to move in the direction *a x*.

If the rays of light, after passing through a medium, enter another of a different density, perpendicular to its surface, they proceed through this medium in the same direction as before, thus the ray represented by P *a*, proceeds to *b*, in the same direction. But if the ray enter obliquely to the surface of a medium, either denser or rarer than that in which it moved before, it is made to change its direction in passing through that medium. Of this sort of refraction there are two cases.

1. If the medium, which the ray enters, be denser, it moves through it in a direction *nearer* to the perpendicular drawn to its surface. Thus, S *a*, supposed to be in air, upon entering the denser medium, A B, glass, or water, instead of proceeding in the same direction, is bent into the direction, *a x*, which makes a less angle with the perpendicular, P *b*.

2. When a ray of light passes out of a denser into a rarer medium, it moves in a direction farther from the perpendicular. Thus, if *x a* were a ray of light passing through glass or water, A B, it will, on arriving at a rarer medium, move in the direction *a* S, which makes a greater angle with the perpendicular. Refraction is greater or less, that is, the rays are more or less bent or turned aside from their course, according as the second medium, through which they pass, is more or less dense than the first. Thus light is more refracted in passing from air to glass, than from air to water, because glass is two or three times denser than water.

The refraction of light is thus shewn; take an empty bason into a dark room, make a small hole in the window-shutter, so that a ray of light may proceed to the bottom at a given point: mark this spot: then without disturbing any thing, pour water into the bason, and the ray, instead of proceeding to the point marked, will be bent out of its first direction, and be found at another point nearer the side.

In repeating the experiment, if a piece of looking-glass be laid at the bottom of the bason, the light will be reflected from it; and will be observed to suffer the same kind and degree of refraction, in going out, as in coming in, only in a contrary direction.

If a few drops of milk be put into the water so as to take away its transparency, and if dust be raised in the room by sweeping a carpet, &c. the rays will be rendered much more visible. Another experiment is shewn on this subject, and may be repeated very easily: put a shilling into an upright bason or pan when empty, and let a person who is to observe the experiment walk backward, till he just lose sight of the money by the side of the vessel. Now pour water into the bason, and the observer will see the shilling most distinctly, though neither he nor it has been removed from their places.

Parallel rays of light are such as move always at the same distance from each other: such are those represented at *a b*, &c. fig. 2. Now if these fall upon a plano-convex lens, that is, a lens, one of whose sides is flat, and the other convex they will be so refracted as to unite in a point, *f*, behind it, called the *focus*, the distance of which from the centre of the glass, is called the focal distance, which is equal to the diameter, or to twice the radius of the sphere, from which the lens is supposed to be cut.

When parallel rays, A B, fig. 3, fall upon a double convex lens, that is, a lens, both of whose sides are convex, they will be refracted so as to meet in a focus, *f*, whose distance is equal to radius, or the semi-diameter of the sphere from which it is taken.

It is evident from the figure, that all the rays of the sun

which fall upon the surface of a convex lens are collected at the focus *f*; of course the force of all their heat is collected into that part, and is in proportion to the common heat of the sun's rays, as the area of the glass is to the area of the focus. As the one may be 10, or 100, or 1000 times larger than the other, the heat at the focus may be 10 times, or 100 times, or 1000 times greater than it is at the surface, which points out the cause why glasses of this shape are used, and act, as burning-glasses.

All the rays on each side the centre one cross that centre ray, and diverge from it to the contrary sides, in the same manner as they converged in coming to it. And if another glass, FG, of the same convexity as AB, be placed in the rays at the same distance from the focus, it will refract them so, as that, after going out of it, they will be all parallel, and proceed in the same manner as they came to the first glass AB; but on different sides of the middle ray, as may be seen by tracing their progress in the figure.

Since rays diverge from a radiant point as from a principal focus, therefore if a candle be placed at *f*, in the focus of the convex glass FG, the diverging rays in the space of F*f*G will be so refracted by the glass, that, after going out of it, they will become parallel, as is shewn in the figure. If, however, the candle be placed nearer the glass than its focal distance, the rays will diverge, after passing through the glass, more or less, as the candle is more or less distant from the focus: but if it be placed farther from the glass than its focal distance, the rays will converge after passing through the glass, and meet in a point, which will be more or less distant from the glass, as the candle is nearer to or farther from its focus; and where the rays meet, they will form an inverted image of the flame of the candle. This may be made evident by placing a paper at the point where the rays meet, see fig. 4 and 5.

If an object, ABC, fig. 6. be placed beyond the focus F, of the convex glass *def*, some of the rays, which flow from every point of the object, on the side next the glass, will fall upon

it; and after passing through it, they will be converged into as many points on the opposite side of the glass, where the image of every point will be formed, and consequently the image of the whole object, which will be inverted. Thus the rays A*d*, A*e*, A*f*, flowing from the point A, will converge in the space *d a f*; and by meeting at *a*, an image will be formed there of the point A. The rays B*d*, B*e*, B*f*, flowing from the point B, will be united at *b*, and those from C at *c*, and so of all the intermediate points between A and C. If the object ABC be brought nearer to the glass, the picture *a b c* will be removed to a greater distance; for then, more rays flowing from every single point, will fall more diverging upon the glass; and therefore cannot be so soon collected into the corresponding points behind it. If the distance of the object ABC be equal to the focal distance of the glass, the rays of each pencil will, as we have seen, be so refracted by passing through the glass, that they will go out of it parallel to each other, and then there will be no picture formed. But where a picture is formed, it will be as much larger or less than the object, as its distance from the glass is greater or less than the distance of the object; so that if ABC be the object, *c b a* will be the picture; or if *c b a* be the object, ABC will be the picture.

When parallel rays as *a b c d*, &c. fig. 7, pass through a concave lens, as AB, they will diverge, after passing through a glass, as if they had come from a radiant point *x*, in the centre of the convexity of the glass: the point is called by writers on Optics, the imaginary or virtual focus. Thus the ray after going through the glass will on coming out at *g*, go on in the line *gh*; and the ray *b* in the direction *mn*, and so of the rest. The centre ray *c*, falling perpendicularly upon the middle of the lens, suffers no refraction in passing through it; but goes on in the same rectilinear direction, as if no glass had been in the way. If the lens had been concave only on one side, and the other side quite flat, the rays would have diverged, after passing through it, as if they had come from a radiant point at double the distance of *x* from the lens; that is, as if the point

had been at the distance of a whole diameter of the glass's convexity.

Of Reflexion. Def. 1. When rays of light strike against a surface, and are sent back again from the surface, they are said to be *reflected.* 2. The incident ray is that which comes from any luminous body, and falls upon the reflecting surface, as ED, fig. 8, and BA is the reflected ray. 3. The angle of incidence, is that which is contained between the incident ray BC, and a perpendicular BH to the reflecting surface in the point of reflexion, viz. CBH. 4. The angle of reflexion is that contained between the said perpendicular HB, and the reflected ray BA, viz. HBA.

When a ray of light falls upon any body, it is reflected, so that the angle of incidence is equal to the angle of reflexion; this is the fundamental fact upon which all the properties of all kind of mirrors depend. If for instance a ray of light from the sun S, fall upon the mirror ED, at the point B, it will be reflected into the line BA; because the angle CBH is equal to the angle ABH, or what is the same thing, the curve line *ei* is equal to the curved line *ix*, which are the measures of the angles just named.

When the parallel rays *a b*, C *d*, *e f*, fig. 9, fall upon a concave mirror AB, they will be reflected back from the mirror, and meet in a point *m*, at half the distance of the surface *b d f*, of the mirror, from C, the centre of concavity: for they will be reflected, at as great an angle from the perpendicular to the surface of the mirror as they fall upon it, with regard to that perpendicular, but on the other side of it. Let C be the centre of the concavity of the mirror AB, and let the parallel rays *a b*, C *d*, *e f*, fall upon the points *b d f*. Draw the lines C *b*, C *d*, and C *f*, from the centre, and these will be perpendicular to the surface of the mirror, because they proceed to it like so many radii from the centre to the circumference of a circle. Now if the angle C *b m* be made equal to the angle C *b a*, *b m* will be the direction of the ray *a b*, after it has been reflected from the point *b* of the mirror. The same

thing will occur with regard to the ray *ef*, which will be reflected along the line *fm*. The ray C*md* passing through the centre of the concavity of the mirror, falls upon it at *d*; and being perpendicular to it, is therefore reflected back in the same line *dm*C: so that all these rays meet in the point *m*, and the same thing would happen to all the rays flowing from any object between the rays *ab* and *ef*, so that the image of the object would be formed at *m*, which point, as has been observed, is distant from the mirror equal to half the radius *dm*C of its concavity.

The rays, which proceed from any celestial object, may be esteemed parallel at the earth, and therefore the images of that object will be formed at *m*, when the reflecting surface of the concave mirror is turned directly towards the object. Hence the focus of the parallel rays is not in the centre of the mirror's concavity, but half way between the mirror and centre.

The rays, which proceed from any remote terrestrial object, are nearly parrallel at the mirror, but not strictly so: they come diverging to it in separate pencils, or, as it were, bundles of rays from each point of that side of the object which is next the mirror: therefore they will not converge to a point at the distance of half the radius of the mirror's concavity from its reflecting surface; but in separate points, at a little greater distance from the mirror: and the nearer the object is to the mirror, the farther these points will be from it; and an inverted image of the object will be formed in them, which will seem to be pendent in the air, and will be seen by an eye placed beyond it (with respect to the mirror), in all respects like the object, and as distinct as the object itself. This may be thus illustrated. Let AB, fig. 10, be a concave mirror, and ME represent any remote object, from every part of which rays will proceed to each point of the mirror, that is, from the point M rays will flow to every point of the mirror, and so they will from E, and from every point between these extremities. We will consider the case with regard to the point M, and take only three rays to prevent confusion, these are MA,

M c and MB, and C is the centre of concavity of the glass, If CA be drawn to the glass, it will be perpendicular to it at the point A, and from what has been said, the angle MAC is the angle of incidence; and as the angle of reflexion is always equal to the angle of incidence, the angle CA*x* must be made equal to MAC, and the line A*x* must be produced. M*c*C made with the ray M*c* and perpendicular C*c*, is another angle of incidence, to which C*cz*, made equal to it, is the angle of reflexion. Again, MBC is another angle of incidence, to which CB*u* is the angle of reflexion. Now the reflected rays Ax, *cz*, and B*u* being produced, cut each other in the point *m*, which is the point at which the image of the extremity M of the arrow will be formed. The same might be shewn of every other part of the object ME, the image of which will be represented by *em*, which is at a greater distance from the glass than half C*c* or radius. It will be observed, that the image is inverted, and less than the object. And generally when the object is more remote from the mirror than its centre C, the image will be less than the object, and will be situated between the object and the mirror: when the object is nearer than the centre of concavity, the image will be more remote from the mirror, and larger than the object: thus if *m e* were the object, the image would be at ME, for as the object recedes from the mirror, the image approaches nearer to it; and as the object approaches nearer the mirror, the image recedes farther from it: all which circumstances are clearly demonstrated in the works to which we shall have occasion to refer.

If the object be exactly in the centre of the mirror's concavity, the image and object will be coincident and equal in bulk. So that if a person place himself directly before a large concave mirror, but farther from it than the centre of concavity, he will see an inverted image of himself in the air, between him and the mirror, but the image will not be so large as himself. If he hold out his hand towards the mirror, the hand of the image will come out towards his hand, till they meet, and

appear as it were to shake hands. If the hand be extended farther, the image will pass by his hand, and come between it and his body: and if the hand be moved a little towards either side, the hand of the image will move towards the other; so that whatever way the object moves, the image will move the contrary way.

Several other experiments of this kind will be found in almost all writers on this branch of science. The following may be mentioned, as very easy to be performed.

Take a bottle or decanter partly full of water, with a cork or stopper in it, and place it opposite a concave mirror, but beyond its focus, in order that it may appear reversed; then stand still farther distant than the bottle, and it will appear in the air inverted, and the water, which is in the lower part of the bottle, will appear to be in the upper. If now the bottle be inverted, the image of the water will appear in the lower part of the bottle. When it is in this inverted state, uncork it; and while the water is running out, the image appears to be filling, but the illusion ceases as soon as the bottle is empty.

The appearance of the image in the air, between the mirror and object, has been productive of many agreeable, and not a few disagreeable deceptions; which, when exhibited with art, and with an air of mystery, have been very successful, and a source of profit to public exhibitors: hence a person has been desired to look into a glass, and a sword, or death's head has appeared to dart out of it.

Of the different Refrangibility of the Rays of Light. 1. Rays of light are said to be differently refrangible, when at the same or equal angles of incidence, some are more turned out of the way than others. 2. Light is called *homogeneous*, that is, of the same kind, when the rays are all equally refrangible; and *heterogeneous*, that is, of different kinds, when some of the rays are more refrangible than others. 3. The colours of homogeneous rays are all primary or simple colours. 4. The rays of the sun are not all equally refrangible, and

those rays, which have a different degree of refrangibility, have likewise a different colour, as may be shewn by the following experiment.

If a beam of light SF, fig. 11, from the sun pass into a dark room through a small hole F, in a window shutter EG, and be received upon a plain surface, a white round image O will be seen; but if a glass prism ABC, is so placed as to receive the beam of light, the rays of this beam, from their refraction in passing the prism, will be turned upwards; and the refracted image PT will be oblong, having its breadth equal to the diameter of the circular picture. If the rays were equally refracted upwards, the refraction would not change the form of the picture. Hence it is naturally inferred, that as the refracted image is oblong, it must be formed by rays differently refrangible, which fall with equal angles of obliquity upon BC, the first side of the prism, but that some of them are in refraction turned more out of the way than others; those rays which go to P, the upper part of the image, being the most refrangible; and those which go to T, the lower part, being the least refrangible. This oblong image is made up of seven different colours, in the following order, beginning with those that are most refrangible; viz. violet, indigo, blue, green, yellow, orange, and red.

To prove that the prismatic image is produced by the different refrangibility of the rays, and by no other cause, let a second prism be placed beyond the first, at right angles to it. The rays passing through the second prism are refracted sideways; those which were most refracted upwards by the first prism, are most refracted sideways by the second; but the rays not being spread in breadth, the image remains of the same form.

Homogeneous light is refracted regularly without any dilatation of the rays. For, by experiment, it is seen that when the rays of any colour in an oblong image, as the green, or the red, are separated from the rest, in the way in which it has been described above, and some of these rays are transmitted through

a small hole in a thin board, and refracted by a prism placed on the other side, the image formed by these rays after refraction will not be oblong, but circular.

Writers on this subject infer that the confused appearance of objects seen through refracting bodies, is owing to the different refrangibility of light. In illustration of this fact, the following experiment is noticed. Small objects placed in a sun-beam, and viewed through a prism, will be seen confusedly; but if they are placed in a beam of homogeneous light separated by a prism, they will appear as distinct through the prism, as when viewed by the naked eye.

The colours of homogeneous light can neither be changed by refraction nor reflection. If a beam of homogeneous light pass through a round hole, in a pasteboard, and are then refracted by a prism on the other side, the colour of the rays will remain the same. Vermilion viewed in homogeneous red light, will be red; but if placed in green, or in any other homogeneous light, it will take the colour of the rays that fall upon it.

The whiteness of the sun's light arises from a due mixture of all the primary colours. For if the oblong picture PT fig. 11, be received by a convex lens, the rays, which were separated at PT, will, by passing through the lens, be collected into a focus, and form a round image of the sun upon a paper or other substance. This image, formed of all the primary rays, is white. That the whiteness of the image is owing to the due mixture of all the sorts of rays, appears from this circumstance, that if any of the colours be intercepted at the lens, the image loses its whiteness.

Water, glass, air, and other transparent substances, when drawn into thin plates, become coloured, as the following experiments will evince. 1. If a soap-bubble be blown up, and set under a glass, so that the motion of the air may not affect it; as the water glides down the sides, and the top grows thinner, several colours will successively appear at the top, and spread themselves from thence in rings down the side

of the bubble, till they vanish in the same order in which they appeared. At length a black spot appears at the top, and spreads till the bubble bursts. 2. If a piece of plain polished glass be placed upon the object-glass of a telescope, and the interval between them be filled up with water, as the glasses are pressed together, the same colours arise at the point of contact, and spread themselves in circular rings round that point in the same order as in the soap-bubble. 3. A convex and concave lens, of nearly the same curvature, being pressed closely together, exhibit rings of colours about the points where they touch. Between the colours there are dark rings, and when the glasses are very much compressed, the central spot is dark. 4. Two pieces of plate-glass wiped clean, and rubbed together, will soon adhere with considerable force, and exhibit various ranges of colours.

From these and other experiments of the like kind, it appears plain, that the colours of bodies depend in some degree upon the thickness and density of the particles that compose them: and if the density or size of the particles in the surface of a body be changed, the colour is likewise changed. Sir Isaac Newton, from a great variety of experiments on light and colours, concluded that every substance in nature, provided it be made sufficiently thin, is transparent: thus gold, when reduced to very thin leaves, transmits a bluish green light. And Mr. Delaval, who, of late years, has done more than almost any other person on the subject, has shewn that colours are exhibited, not by reflected, but by transmitted light. See Memoirs of the Manchester Philosophical Society, Vol. II.

Some portion of light is reflected from every surface of a body, or from every different medium into which it enters. Thus transparent bodies reduced to powder, and water in the shape of froth, appear white, which is no other than a copious reflection of light from all the surfaces of the minute parts, and from the air interposed between them.

The Rainbow is a meteor in form of a party-coloured arch,

or semicircle, exhibited only at the time when it rains, and is always seen in that point of the heavens which is opposite to the sun, and it is occasioned by the refraction and reflection of his rays in the drops of falling rain. There is likewise, though not always distinctly visible, a secondary, or much fainter rainbow, investing the former at some distance. This beautiful phenomenon has engaged the attention of persons in all ages, but the cause of it could not be ascertained till the discoveries concerning the division of the rays of light into their primary colours, were made.

The doctrine of the different refrangibility of light enables us to give a reason for the size of a bow of each particular colour. All the phenomena of the rainbow are explained in elementary works according to the principles of Sir Isaac Newton. To these works we shall refer, mentioning in this place only the facts upon which the phenomena depend.

1. When the rays of the sun fall upon a drop of rain, and enter into it, some of them after one reflection and two refractions, may come to the eye of a spectator, who has his back turned towards the sun, and his face towards the rain. Of the rays of light reflected from a drop of rain coming to the eye, those are called effectual, which can excite a sensation; and they will not be effectual, when they come out of a drop of rain unless they are parallel and contiguous.

When the sun shines upon the drops of rain as they are falling, the rays that come from those drops to the eye of the spectator, after one reflection and two refractions, produce the primary rainbow, which is never larger than a semicircle.

When the sun shines upon the drops of rain as they are falling, the rays that come from these drops to the eye of a spectator, after two reflections and two refractions, produce the secondary rainbow. The colours of the secondary rainbow are fainter than those of the primary rainbow, and are ranged in the contrary order. For the primary rainbow is produced by such rays as have been only once reflected, the secondary rainbow is produced by such rays as have been twice reflected.

But at every reflexion some rays pass out of the drop of rain without being reflected, so that the more frequently the rays are reflected, the fewer of them are left to excite a sensation in the eye, therefore the colours of the secondary bow are produced by fewer rays, and consequently will be fainter than the colours of the primary bow.

In the primary bow, reckoning from the outside of it, the colours are ranged in the following order: red, orange, yellow, green, blue, indigo, violet. But in the secondary bow, reckoning from the outside, the colours are reversed, and are ranged: violet, indigo, blue, green, yellow, orange, and red. So that the red, which is the outermost or highest colour in the primary bow, is the innermost or lowest colour in the secondary one.

Of the Eye. Having described the nature of the refraction of rays of light, as performed by different kinds of lenses, we shall shew the effects produced by the several parts of the eye intended for vision.

The eye is of a globular form, and composed of three *coats* or teguments, one covering the other, and enclosing three different substances called *humours.* Fig. 12 is intended to shew the section of the globe of the eye, the three concentric circles representing the three coats. The external coat, which is represented by the circle ABCDE, is called the sclerotica, of which the front part C x D is perfectly transparent, and is called the *cornea,* beyond this towards B and E, it is white, viz. those parts that are called the white of the eye.

The second circle represents the *choroides,* which encircles the eye entirely, excepting at the small opening usually called the pupil of the eye, that is, the space through which the rays of light pass on to the back of the eye, called the *retina.* The choroides is distinguished into two parts, of these the larger portion, which is not visible, is peculiarly denominated the choroides; and the front, viz. that part which is blue, or grey, or black, or brown, in different eyes, is called the *iris.* The iris is composed of a sort of net-work, which contracts or ex-

pands according to the force of the light to which the eye is exposed. In a very strong light the iris is enlarged, and the pupil becomes small; in the dusk, or in a darkish room, the iris contracts, and the pupil becomes large, to admit all the light that can be had, the iris being perfectly opake, and admitting no rays through it.

The third coat, represented by the inner circle, is called the *retina,* so named from its net-work form: it serves to receive the images of objects produced by the refraction of the different humours of the eye. From the hinder part of the eye, but not in the centre, proceeds the optic nerve A, which conveys to the brain the sensation produced upon the retina. Before however we come to speak of the manner of vision, which is dependent on sensation, we shall describe the three *humours,* as they are called, included within the coats; these are the *aqueous,* the *crystalline,* and the *vitreous* humours.

The aqueous is much more of a fluid than the others: it is, in comparison of those, thin and clear like water, and it fills up all the front part of the eye under the cornea; viz. the part distinguished by the letters *c x e b a:* the lens-like part *f d* is the crystalline humour enveloped by the aqueous humour in front, and by the vitreous humour on the back, which fills up all the space *z d f z.* Fig. 13 is the representation of the eye as it is seen in the head, in which *c* A and *c* B represent the cornea, *a c* and *a b* the iris that encircles the pupil *x.*

Of the way in which Vision is performed. As every point of an object to which the eye is directed, sends out rays in all directions, some rays, from every point on the side next the eye, will fall upon that part of the cornea between *a* and *b;* and on passing through the pupil and humours of the eye, they will be converged to as many points on the retina of the eye, and will form on it a distinct picture of the object. This is chiefly done by means of the crystalline humour, which is, and which acts as, a completely double convex lens. There is no doubt that objects become visible to the eye, by the sensation which their images thus painted on the retina of the

eye excite, and which is carried by the optic nerve A to the brain.

Of spectacles, and their uses. Many persons, it is well known, are defective in the organs of sight: the defect may arise from disease or the malformation of the parts of the eye. Some eyes are too flat, others are too convex. In some, the humours just described lose a part of their transparency, and on that account, a deal of light that enters the eye, is stopped, and lost in the passage, and every object appears dim.

Spectacles are intended to remedy the defects of a short sight, whether it arise from a too great or too small degree of convexity. When the eyes are too flat, convex lenses are made use of; and if the eyes are already too convex, the defect may be remedied by concave glasses.

The property of a convex lens is, as has been shewn, to cause the rays of light to converge sooner than they would without its intervention. In eyes that are flatter than they ought to be, the rays do not converge, when they reach the retina, and on that account objects are seen confused; but by the interposition of a convex lens, they are made to converge at the right place exactly. The property of a concave lens, is to cause the rays to diverge, and it is useful to those persons whose eyes are too round: for to them the rays of light naturally converge to a point before they reach the retina: but as sensation is excited on the retina only, such persons cannot see those objects, the rays from which converge before they reach the retina. They do not however stop, but cross each other, and will excite confused sensations, such as will not convey the idea of distinct vision, because they are not brought to a focus on the retina; a concave lens by causing the rays to diverge, prevents them from converging till they arrive at the retina.

Of Optical Instruments. The microscope is an instrument intended to examine small objects. The human eye cannot distinctly view an object that is nearer to it than about six inches; and since there are very many objects, which at

that distance appear either as points, or are wholly imperceptible, whatever instrument will render such minute objects visible and distinct, is called a microscope.

Microscopes, in common language, are said to magnify the objects which are seen through them; this however is true only with regard to the apparent, not the real magnitude of the objects. The apparent magnitude of objects is measured by the angle under which those objects are seen by the eye. Hence an object at the distance of half a mile, will appear twice as large as it would if it were at a mile's distance; because the angle, which it would make on the eye, would be twice as large in the one case as in the other. Upon the same principle, if at the distance of six or seven inches, we can but just discern an object, and then by interposing a lens, or other body, we can view that object at a nearer distance, the object will appear as much larger through the lens than it did to the naked eye, as its distance from the lens is less than its distance was from the eye. That this is not because the object is magnified by the lens, is evident from the circumstance, that the same thing will happen, if instead of a lens, a piece of brown paper with a small hole, made with a pin, or needle, be interposed between the object and the eye. If the eye be brought within an inch or two of a book, it will be impossible to distinguish the letters; but if, at the same distance, it be examined through a hole in a piece of dark coloured paper, the letters will not only be visible, but apparently very much magnified. This would not be the case if the print were seen through the same hole at the distance of six or seven inches from it.

There are three kinds of microscopes, viz. the single, the compound, and the solar, each of which has its peculiar advantages. The single microscope consists of one lens, by means of which a great number of rays, proceeding from a point, become united; and as each ray carries with it the image of the point from whence it proceeded, all the rays united must form an image of the object; and the more of

these rays that are united, the brighter will the object appear. The single lens removes the confusion that invariably accompanies objects when seen very near by the naked eye; and it magnifies the diameter of the object in proportion as the focal distance is less than the limit of distinct vision, which may be reckoned from six to eight inches.

The lens used in a single microscope is always double convex, and the focal distance of a double convex lens is equal to the radius of convexity. If therefore in a common reading-glass the focal distance be two inches, and the limits of distinct vision be reckoned eight inches, it will apparently magnify objects four times, because the power of the single convex lens may be calculated by dividing the distance of distinct vision by the naked eye, by the focal distance of the lens, that is, in this case, $\frac{8}{2}=4$. If the focal distance were $\frac{1}{4}$ or $\frac{1}{8}$ of an inch, then the magnifying power would be found by dividing 8 by $\frac{1}{4}$ or $\frac{1}{8}$; but to divide a whole number by a fraction, is to multiply the said number by the denominator of the fraction, thus $8 \div \frac{1}{4} = 32$ and $8 \div \frac{1}{8} = 64$, of course lenses of these descriptions are said to magnify 32 and 64 times. Hence it appears, that the smaller the lens, the greater is its magnifying power; and Dr. Hooke has asserted in his "Micrographia," that he has made lenses so small as to render objects visible, of which a million times a million would hardly be equal to the bulk of a grain of sand.

One of the most common compound microscopes is represented in fig. 14; *c d* is called the object-glass, and *e f* the eye-glass. The object *a b* is placed somewhat farther from *c d* than its principal focus, so that the pencils of rays flowing from the different points of the object, and passing through the glass, may be made to converge and unite at as many points between *g* and *h*, where the image of the object will be formed. This image therefore, and not the object itself, is viewed by the eye-glass *e f*, which is so placed that the image *g h* may be in the focus, and the eye at about an equal distance on the other side: the rays of each pencil will be parallel after

going out of the eye-glass, as at *e* and *f*, till they come to the eye at *k*; by the humours of which, already described, they will be converged and collected into points on the retina, and form the large inverted image AB.

The solar microscope consists of a looking-glass SO without side a window, the lens *a b* in the shutter *x z*, and the lens *n m* within a darkened room. These three parts are united to, and placed within, a brass tube. The looking-glass can be turned by the adjusting screw, so as readily to receive the incidental rays of the sun represented by S, S, S, and reflect them through the tube into the room. The lens *a b* collects those rays into a focus at *n m*, where there is another lens: here the rays cross, and diverge to the white screen on which the image of the object will be painted.

Microscopes are varied in their construction, but it is sufficient in this work to explain the general principles, leaving our readers to investigate the minutiæ in the works to which we shall shortly refer them.

Of Telescopes. The telescope is an optical instrument for viewing, as the word imports, distant objects. This instrument is considered as one of the noblest and most useful that was ever invented by human ingenuity. By means of it, in its present improved state, and in the hands of the celebrated Herschel, the wonders of the heavens have been discovered, and astronomy brought to a degree of perfection of which former ages could have had no conception.

Telescopes are either *refracting* or *reflecting*: the *former* consist of different lenses, through which the objects are seen by rays refracted, and sent to the eye; and the latter of specula and lenses, from and through which, the rays are reflected and passed to the eye. The lens next the object is called the object-glass; and that next the eye, is called the eye-glass; and when the telescope consists of more than two lenses, all but that next the object are usually denominated eye-glasses.

As in the microscope, so in telescopes, the leading characteristics depend upon this principle, " that objects appear

larger in proportion to the angles which they subtend at the eye;" and the effect is the same, whether the pencils of rays, by which objects are visible to us, come directly from the objects themselves, or from any place nearer the eye, where they may have been united, so as to form an image of the object; because they issue again from those points in certain directions, in the same manner as they did from the corresponding points in the objects themselves. All therefore that is effected by a telescope, is first to make such an image of a distant object, by means of a lens or mirror, and then to give the eye some assistance for viewing that image as near as possible; so that the angle, which it subtends at the eye, may be very large, compared with the angle which the object itself would subtend in the same situation. This is done by means of an eye-glass, which so refracts the pencils of rays, as that they may afterwards be brought to their several foci by the natural humours of the eye.

There are several kinds of telescopes, distinguished by the number and form of their lenses, or glasses, and denominated frequently from the particular uses to which they are chiefly applied: thus we have terrestrial, and celestial or astronomical telescopes, according as they are applicable to land objects or to the heavenly bodies: we have likewise the Galilean and the Newtonian telescopes, so named from the inventors; and we have the refracting, the reflecting, and the achromatic telescopes.

The common *refracting* telescope consists of two tubes and two glasses: the tubes are intended for the purpose of holding the glasses, and for confining the boundary of the view. Let AB, fig. 16, represent the eye of an observer, $m\,n$ the eye-glass, and $g\,h$ the object-glass: $x\,y$ is the object to be viewed. In this figure, the eye-glass is a double concave lens, because the convex lens of itself would converge the rays too quickly, and bring them to a focus in the eye at E instead of at the back of the eye on the retina, which would render the object confused; besides, by coming to a focus at E, the image is very

small, in comparison of what it is when formed on the retina. By examining the figure, it will be seen that there are two pencils of rays flowing from the extremities of the object: the rays of the pencil, that proceed from *x*, go on diverging till they reach the convex lens *g h*, when they will be so refracted by passing through the glass, as to converge and meet in the point, in the eye, *x*. The same may be said of the pencil of rays that proceeds from the point *y*, and likewise of all the pencils of rays flowing from the object between the points *x* and *y*; so that the image of the arrow would, by the convex lens, be formed at E. If there were no other glass, the rays would cross each other at that point, become divergent, and there would be no distinct image formed; but every point would be spread over a large space, and the image would be confused. To prevent this, the concave lens is interposed, and the pencil of rays, which would by the convex glass have come to a point at *y*, will now be made to diverge so much, as to throw the focus of the rays to *b* instead of *y*, and thus the image of the object is enlarged on the retina.

As the eyes of different persons are differently formed, as to the exact shape of the several humours, so the tubes of telescopes are made to slide in and out, in order that the foci of the glasses may be so adjusted to the eye as to cause the image to fall precisely on the retina; by which means it is not only enlarged, but becomes quite distinct.

Refracting telescopes are variously formed; sometimes with two, and sometimes with more than two lenses. They are chiefly used for observing terrestrial objects, and therefore it is requisite that they should exhibit those objects in an upright position, and so as to afford a large field of view, that is, as much of the landscape as possible.

It is not necessary that the eye-glass should be concave, as is evident by referring to fig. 17: in this a double convex *g h* is substituted instead of a concave one. The focus of the object-glass is at E, and the lens *g h* must be so much more convex than *o p*, as that its focus shall also be at E; for then

the rays flowing from the object $x\,y$, and passing through the object-glass $o\,p$, will form the inverted image m E d; and by means of the double convex gh, the image is thrown upon the retina, and it is seen under the large angle D e C, that is, the image m E d will be apparently enlarged to the size CED.

Refracting telescopes magnify in proportion as the focal distance of the object-glass is greater than the focal distance of the eye-glass: thus if the focal distance a E of the object-glass be 12 inches, and that of the eye-glass only a single inch, the telescope magnifies the diameter of an object 12 times, and the *whole surface* of the object will be apparently magnified 144 times, that is, such a telescope will shew a small object 144 times plainer or more distinct than it could be seen by the naked eye. For it should be observed, that telescopes in general represent terrestrial objects to be nearer rather than larger: thus, looking at any small object at an hundred yards distant by means of a telescope that magnifies 100 times, it will not appear to be larger than it really is, but at the distance only of a single yard instead of a hundred.

From what has been said of the method of calculating the power obtained by the refracting telescope, it is evident that when very high powers are required, the instrument must be of considerable length, because we cannot go beyond a certain point in the different proportions between the focal distances of the object and eye-glass. An object-glass of ten feet focal distance will not admit of an eye-glass with a focal distance so little as two inches and a half; and an object-glass of 100 feet will require an eye-glass of full 6 inches: now as the magnifying powers are ascertained by dividing the focal distance of the object-glass by that of the eye-glass, the magnifying powers of the telescopes of 10 and 100 feet in length will be as 10 divided by $2\frac{1}{2}$ inches; and as 100 feet divided by 6 inches, or $\frac{120}{2.5}$ inches; and $\frac{1200}{6}$ that is, 48 and 200 times. On this account refracting telescopes of high powers become extremely

inconvenient; and therefore they give way to *reflecting telescopes*, of which one, six feet long, will magnify as much as a refractor of 100 feet. These were invented by the illustrious Newton, though they have been almost indefinitely improved since his time. The following description will render the construction of one of the common reflectors intelligible.

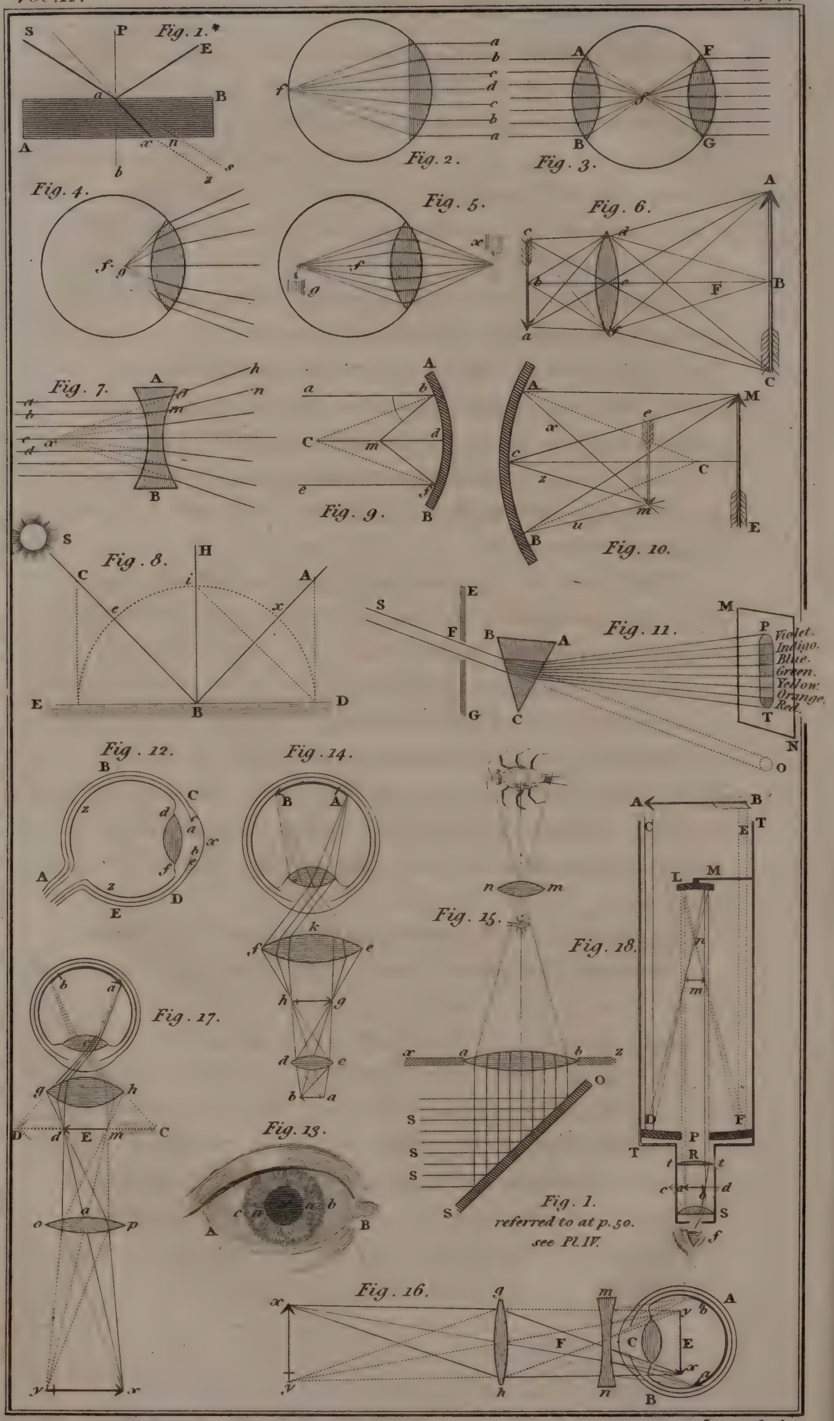
There is a great similarity between *convex lenses*, and *concave mirrors;* that is, as we have seen, they both form an inverted focal image of any remote object, by the convergence of the pencils of rays, and on that account the concave mirror may be substituted for the convex lens. Let T T, fig. 18, represent the large tube, and *t t*, the small tube of the telescope, at one end of which is D F, a concave mirror, with a hole in the middle part at P, the principal focus of which is I K: opposite to the hole P, is a small mirror L, concave towards the great one, and fixed on a strong wire M, which may, by means of an adjusting screw, be moved backwards or forwards. Suppose A B to be a remote object, from which rays flow to the mirror D F. The rays coming from A and B, along the lines at C and E, fall upon the mirror at D and F, are reflected, and form an inverted image at *m;* but as there is nothing to receive the image at that place, they proceed towards the reflector M, crossing each other at *n*. From the mirror M, the rays are reflected nearly parallel through the hole, P: they then pass the plano-convex-lens R, which causes them to converge at *a b*, and the image is now painted in the small tube near the eye, which image is magnified by the lens at S, by means of which it will be seen under the angle *c f d*, so as to appear of the length *c d*, instead of the length *a b*. Dr. Herschel's telescope, made upon this principle, is nearly forty feet long, and four feet ten inches in diameter, and it magnifies 6000 times.

The *Camera Obscura*, another optical instrument, is made by a convex lens placed in the hole of a window-shutter, and if the room be darkened, and no light admitted but that which comes through the glass, the pictures of all objects, as trees,

buildings, men, &c. on the outside, will be shewn in an inverted order, on the white paper placed in the focus of the lens. Instruments of this kind are of various construction, and adapted to different purposes.

The *Magic Lanthorn* consists of a tin lanthorn, having a lamp within, the light of which passes through a plano-convex lens placed in a tube fixed in the front. By means of this, small transparent paintings, on glass, placed before the lens, are strongly illuminated, and the images of them are painted on a screen intended to receive them. This instrument, which was invented as a mere plaything, has of late years been employed for more important purposes, by adapting to it figures that will explain the principles of astronomy, botany, &c.

The *Phantasmagoria* produces an exhibition very similar to that of the Magic Lanthorn. In the common Magic Lanthorns, the figures are painted on glass, and the parts of the glass not occupied by the painting are transparent, of course the image on the screen is a circle of light having a figure upon it; but in the Phantasmagoria, all the glass is opaque, except the figure only, which being painted in transparent colours, the light shines through it; of course no light can come upon the screen but that which passes through the figure itself, consequently the figure only is visible on the screen, without any circle of light. In the common lanthorn the representation is made on the wall, or on a sheet, but in the Phantasmagoria it is thrown upon a silk screen placed between the lanthorn and the spectator. The appearance of the image approaching and receding, is owing simply to the removing the lanthorn farther from the screen, or bringing it nearer to it: for the size of the image increases as the lanthorn is carried back; and as no part of the screen can be seen, the figure appears to be formed in the air, and to move farther off when it becomes smaller, and to come nearer as it increases in size, though it is in both cases at the same distance, viz. painted on the screen, which is not known, by the spectator, to exist.



Lowry Sculp.

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Among the many works published on the science of Optics, may be mentioned the following: adapted to persons of different capacities and attainments in science.

"Scientific Dialogues," vol. v. being part of the series already noticed, intended for those who have a taste for science without having entered much into the elements of it.

"A Short System of Optics, principally designed for the Use of Under-graduates in the University of Dublin, by the Rev. John Stack." This little work, though rarely to be met with in England, deserves notice on account of its excellence as a compendious introduction to the science of Optics. The reader will be required to know the elements of common geometry, as the demonstrations of Mr. Stack, though very easy, are purely geometrical.

"The Elements of Optics, by James Wood, B.D.," make part of the Cambridge course of Mathematics and Natural Philosophy. In addition to the same subjects treated on by Mr. Stack, it enters at large on the Aberrations, produced by the unequal refrangibility of different kinds of rays, and by the spherical form of reflecting and refracting surfaces: a short section is devoted to the doctrine of Caustics. This is more abstruse, and requires a larger share of mathematical knowledge than the preceding, or than the next which follows.

"A Treatise of Optics, containing Elements of the Science, in two books, by Joseph Harris, Esq. late His Majesty's Assay-Master of the Mint," 4to.

Those persons, who have not leisure, nor perhaps a sufficient share of mathematical knowledge to go through the whole of "Dr. Smith's Complete System," hereafter to be mentioned, will find Mr. Harris's treatise a valuable introduction to the science of Optics. It is, indeed, in general, but a compilation; the materials, however, that compose it, are arranged with judgment and perspicuity; and the demonstrations are neat and easily comprehended, by those students

who have laid a proper foundation in the elements of mathematics. In the *first* book, the elementary part of optics is explained: after the necessary definitions, the author demonstrates the various laws of refraction and reflection:—he then illustrates the rationale and effect of lenses of different figures; and after having laid down the theory of the reflection and refraction of light, Mr. Harris, in the *second* book, explains the subject of vision.

"A New and Compendious System of Optics, by Benjamin Martin," is a popular treatise, illustrated with experiments and examples; of the latter, many are worked by common arithmetic. This, like several other of Mr. Martin's works, abounds with typographical errors.

"A Complete System of Optics, in four books, by Robert Smith, LL. D. Professor of Astronomy and Experimental Philosophy at Cambridge," 2 vols. 4to.

The first part of this elaborate work, is designed for the use of those who would know something of Optics, but who want the preparatory learning that is necessary for a thorough acquaintance with the subject. With this view the author has avoided all geometrical demonstrations, and substituted the more entertaining sort of proof, drawn from experiments that may be repeated with little trouble or apparatus. By this means any one with moderate application, may make himself master of no inconsiderable part of the doctrine of optics. The second book is a complete mathematical treatise of the science; and will require, in the reader, a large portion of geometrical and algebraical knowledge. In the third book is given a description of a complete set of optical instruments, with explanations of the various uses to which they may be applied, in Astronomy, Geography, Navigation, Levelling, &c. An history of the telescopic discoveries in the heavens, is the subject of the fourth book, which modern discoveries have, of course, rendered imperfect.

"The elementary parts" of Dr. Smith's Optics, were published by Dr. Kipling, in 1778, who added, in the form

of notes, some explanatory propositions from other authors, chiefly from Dr. Barrow and Descartes.

To the elementary works on the science of Optics generally, may be added the following on a particular branch of it.

"Of Microscopes, and the discoveries made thereby; illustrated with many plates, by Henry Baker, F.R.S." This work, which consists of two volumes octavo, contains much useful knowledge exhibited in a simple and perspicuous method, for the sake of persons who have not had the advantage of a learned education. The reflections, which Mr. Baker draws from the various parts of these volumes, all tend to impress the reader with just ideas of the wisdom, power, and goodness of the great Creator. "The minute living animals exhibited in the second part of this work, will excite a considerate mind to admire in how small a compass life can be contained, what various organs it can actuate, and by what different means it can subsist. They will also shew that the hand which made them, is not confined to size or form: and that it has not been wanting to bestow on creatures almost invisible, and seemingly inconsiderable, every member and faculty convenient to their happiness." These volumes, which were long extremely popular, and went through many editions, have given way, in a great measure, to a work of the same kind, in 4to. by Mr. Adams. And within the last year or two, the author of "the Scientific Dialogues," has published "Dialogues on the Microscope," in two small volumes, which include what is important and interesting in Baker, and the discoveries of all the latest writers on this subject. This work contains an account of the principles of vision, and of the construction and management of the most improved and generally useful microscopes, with their application to the discoveries made by them in the different kingdoms of the natural world. They are accompanied with eight highly finished plates, by Mr. Porter.

CHAP. IV.

NATURAL PHILOSOPHY,

Continued.

Electricity, History of—General principles of electricity—Substances, how divided—Electrical machine and experiments—Attraction and Repulsion—Leyden phial—Electrical spark, shock, and battery—Writers: Priestley—Scientific Dialogues—Adams—Cavallo—Lord Mahon—Brook—Bennet. Galvanism, Discovery of—Experiments—Galvanic circles—Theory. Voltaism—Batteries—Experiments Sir H. Davy's discoveries—Writers: Valli—Fowler—Aldini—Davy. Magnetism—of the Magnet—Attraction and Repulsion—Polarity of the Magnet—Variation of the Magnet—Mariner's Compass—Writers: Cavallo—Lorimer—Churchman.

ELECTRICITY. The word electricity denotes a peculiar state, of which all bodies are susceptible, and which is supposed to depend upon the presence of a certain substance called the electric fluid. Some of the phenomena peculiar to electricity, were known to the ancients, particularly those attractions and repulsions which a piece of amber, after being rubbed, or excited, as it is called, exhibits with regard to hairs, feathers, and other small bodies, and the name electricity is derived from the Greek word denoting amber. Thales, who lived 600 years before the Christian æra, was the first person who observed the electrical properties of amber; but with him

the subject seems to have died, for nothing more appears on the page of history, till Theophrastus, who notices the attractive power of the excited *Tourmalin;* and from this period till the beginning of the eighteenth century, a space of 1900 years, there is almost a complete chasm in the history of electricity.

In the year 1700, Dr. Gilbert, who is esteemed the father of the English electricians, wrote a work entitled "De Magnete," which contains a variety of electrical experiments, and by which it appears he took much pains to discover substances that possessed the power of electric excitation. The great Mr. Boyle, in the year 1670, had applied himself to this subject, and enlarged the catalogue of these substances. Sulphur globes were now made use of to obtain greater powers of electricity than had ever before been had. Otto Guericke, the contemporary of Boyle, discovered electric repulsion: he not only saw the electric light, that had been observed by Boyle, but heard the hissing sound which was emitted. Sir Isaac Newton observed that the electric attraction and repulsion penetrated through glass. Mr. Hawksbee was the first person who applied a glass-globe to the machine, and he made many very important discoveries. In 1729, Mr. Gray found out the difference between electrics and conductors, and soon after this was discovered the difference between positive and negative electricity. Muschenbroek, in the year 1746, accidentally discovered the accumulation of the electric power in the Leyden phial. From this time electricity became the general subject of conversation, and, as a science, it advanced with great rapidity under the auspices of Franklin, Priestley, and others. Of electricity, as well as of optics, the last named philosopher is known as the interesting and elaborate historian.

General principles. The earth, and all bodies with which we are acquainted, are supposed to contain a certain quantity of an exceedingly elastic invisible fluid, called the electric fluid. This certain quantity belonging to all bodies, may be called their natural share; and which of itself, in its dormant

state, produces no sensible effect; but as soon as the equilibrium is disturbed, and any body, or surface of a body becomes possessed of more or less than its natural share, it exhibits the phenomena of attraction and repulsion, and other remarkable effects are produced according to the quantity of excitation.

The equilibrium could never be disturbed, or if it were, it would be immediately restored, if the bodies in, or on which it was disturbed, admitted to it a free passage, either along their surfaces, or through their pores. As this is not the case with some bodies, whenever any of these has acquired an additional quantity of electric matter, and is at the same time every where surrounded with bodies through which it cannot pass, it must remain overcharged: or if it has lost a part of its natural quantity, it must in like circumstances remain exhausted.

All substances are divided by electricians into two classes called *electrics* and *non-electrics*. Electrics do not suffer the electric matter to pass readily over their surfaces, and hence they obtain the name of *non-conductors*. Non-electrics do permit the electric matter to pass readily over their surfaces, and on that account they have been denominated *conductors*.

Glass, resin, sealing-wax, sulphur, bees-wax, and baked wood, are the most perfect non-conductors among solids, and oils, and dry air among fluids. But heat and moisture render all substances conductors.

According to the theory of Franklin, which seems best adapted to the explanation of facts, when a body has more than its natural quantity of this fluid, it is said to be positively electrified, and the electricity which it contains is called positive electricity; and when it has less than its natural share, it is said to be negatively electrified. When a conductor is so surrounded with non-conductors, that the electric fluid cannot pass from it into the earth, it is said to be *insulated*, such is the case of a piece of metal supported upon a glass pillar.

The electric fluid is generally brought into action by friction, though there are other means of disturbing the equilibrium. The chief electric appearances are the attraction and

repulsion of light bodies; fiery sparks attended with a snapping noise; pencils of light proceeding from, or entering into an electrified body upon the approach of other substances.

If a glass tube two or three feet in length, and an inch or more in diameter, be briskly drawn through the hand, or rubbed with a piece of dry and warm silk, the effect of that friction is, that the electric matter leaves the hand, and passes upon the glass, where it will remain; for as the glass, and the dry air which surrounds it, are non-conductors of electricity, this redundancy of the electric matter cannot flow away; but if any conducting substances, as the finger, or a piece of metal, be presented to the glass, the electric fluid will pass from that part into them, attended with a crackling noise. The tube thus excited will attract any light substances, as morsels of paper, &c.; which will, when brought near, spring to it; and after a few seconds, when they seem to have obtained a certain portion of the electricity of the glass, they will be repelled from it. This, and all electrical experiments are best seen in a darkened room.

Although the electric fluid may be excited with the hand on glass tubes, or on sticks of sealing-wax rubbed briskly with flannel, or on the sleeves of a man's coat; yet the quantities so obtained are very small in comparison of what may be collected by other means, as an electrical machine, and of what may be wanted for experiments on a large scale.

Fig. 1. Plate IV. represents an electrical machine; the construction is evident, almost at first sight. EF is a glass cylinder turned by the handle I, and the whole frame is fastened to a strong table by iron clamps. K is a rubber made of silk, or leather stuffed with horse-hair, and L is a silk flap fastened to it, and covering part of the cylinder, to prevent the dispersion and escape of the electric fluid. The rubber is fastened to a spring, which proceeds from a socket cemented on the top of the glass pillar M. There is another strong glass pillar N, on which is fixed a hollow metallic cylinder O P, called a prime conductor, to one end of which is attached a row of pointed wires

at Q, to collect the electric fluid from the glass cylinder; and at the other end is a knobbed wire, from which electric sparks of great length may be drawn.

When the cylinder is turned briskly, the friction of the glass against the rubber causes the electric fluid, which was in the rubber, to pass to the glass; from whence it is conveyed by means of the points to the prime conductor, which, when other bodies, as the knuckle of a person's hand, are presented to it, will give out visible sparks. To obtain a constant supply of the electrical fluid, a brass chain is hung on the knob K, which communicates with the ground, whence the electric fluid is brought in great quantities.

If instead of a transparent glass cylinder, one of sulphur, of sealing-wax, or of rough glass, were made use of, the effect of the friction would be, that a quantity of electric matter naturally belonging to those substances, passes from them to the hand; and these being surrounded with air, which is a non-conductor, remain exhausted, and ready to take sparks of electric fire from any bodies that are presented to them. The sulphur, &c. in one case, though deprived of their share of electricity, are said to be excited, as well as the glass which was overloaded with it; because, though the states they are in be the reverse of one another, the effects produced by them are very similar.

The electricity produced by the excitation of glass is called positive electricity, and by some writers *vitreous:* that produced by sealing-wax, &c., is called negative or *resinous* electricity.

To prove that the earth is the grand reservoir of the electric fluid, let the chain be taken from the rubber, and thus the communication with the earth is cut off; then whatever friction is applied, the quantity of electric fluid obtained will be very small. Let the chain now be put on to the conductor R, and made to hang on the ground, or on the table connected with the ground, and the electric fluid will again be abundant, and may be received from the cushion. Now it passes up the chain, along the prime conductor, and so on to the cushion;

whereas, when the cushion is connected with the earth by the chain, and the conductor insulated, it passes from the cylinder through the points to the conductor. Hence an electrical machine may be made to produce negative and positive electricity: the former by connecting the prime conductor with the earth, by a chain, and taking the fluid from the rubber; the latter by making the rubber communicate with the ground, and taking the fluid from the conductor. Electrify two insulated conductors by placing one before the cylinder, and connecting the other with the cushion, and they will exhibit different kinds of electricity; the same substances which the one attracts, will be repelled by the other; and if the two conductors be brought near each other, a strong spark will pass from one to the other, and thus the equilibrium will be restored. But if both the conductors be placed before the cylinder, they will be equally electrified with the same electricity; and what is attracted and repelled by the one, will be attracted and repelled by the other likewise, and no spark will pass from one to the other by their being brought ever so near. In the foregoing experiment, the conductor connected with the cushion is said to be negatively electrified: that placed before the glass cylinder is said to be positively electrified.

Of electrical Attraction and Repulsion. If two bodies be electrified with the same electricity, they repel each other: if one be electrified positively and the other negatively, they attract each other. A body not electrified will be attracted by those that are, whether they be electrified positively or negatively.

Electrify a pair of insulated pith balls, fig. 2, that is, balls suspended on threads of silk, by bringing them near a prime conductor, or any other substance that is in a state of electric excitation, and they will repel each other.

If one pair of insulated pith balls, electrified negatively, and another pair positively, be brought near, they will attract each other, and both pairs will collapse. Light feathers,

hair, pieces of paper, &c. connected with the prime conductor, are, when electrified, attracted by any non-electric body.—The hair of a person, who, when standing on an insulated stool, is electrified, becomes repellent. Small downy feathers, pieces of leaf gold, paper images, and other light bodies, brought near the conductor, are first attracted, and then repelled.—If a tuft of feathers be placed on the hole *x* of the prime conductor, and then electrified, they will repel each other, and put on a beautiful appearance; but the moment a spark is taken from the conductor, they will fall down into their first position.

When a glass tube, excited either by the hand or a flannel rubber, is brought near a small feather, it will attract it; and when the feather is saturated with the electric fluid, it will fly off towards any other conductor, upon which it may discharge its superabundant electricity: if, however, it be pursued by the tube, while in the electrified state, it will fly away from it, and may thus be driven about in any direction without being touched. A great number of other experiments, instructive, and very interesting, to shew the effects of electric attraction and repulsion, are given in all the elementary books.

Upon this principle have been constructed various kinds of electrometers, of which the one by Mr. Henley is the most simple. It is represented by fig. 3, and is generally fixed in *x*, on the prime conductor, though it is adapted to other parts of the apparatus. It consists of a light rod and pith ball A, turning on the centre of a semicircle B, so as to keep constantly close to the graduated limb. When the prime conductor is electrified, the ball ascends towards B; and according as the charge is lower or higher, the ball ascends to less or greater heights.

Of the electrical Spark. If any conducting substance is presented to the charged prime conductor, the electric matter will pass with violence, in a brilliant spark, from one to the other: and if the conducting substance thus presented, be itself insulated, it will only take a part of the charge from the

prime conductor; and the whole of the redundant electricity being distributed between them, they will give out a smaller spark to any other body that is presented to them.

If a person stand upon a stool with legs made of glass, and take in his hand a chain fastened to the prime conductor, and the machine be put in action, every part of his body will exhibit the same appearances of attraction and repulsion, &c. which the prime conductor itself will do. Sparks also may be taken from him, which will be as painful to the giver, as to the person who receives them. These sparks, when taken from the knuckle in a spoon containing spirit of wine, a little warm, will inflame the liquor, in the same way as it would be lighted with a candle. Not only are the senses of feeling, seeing, and hearing, sensibly affected, but the sense of smell also.

Of the Leyden Phial, and electrical Shock. A glass jar or phial coated on both sides, with tin-foil, except about two inches from the top, is called a Leyden jar or phial: such is that represented in fig. 4. If the inside of this jar is electrified by means of a chain hanging from the prime conductor into it, while the machine is turned, and the outside of the jar is connected in some way or other with the earth, it is said to be charged. In this state the inside has a larger portion of electricity than its natural share, and the outside a smaller portion; and if a communication be made from one side to the other, by a conducting substance, as a discharging rod (see the figure) an explosion will take place, that is, the superabundant portion of the inside will pass with great violence to the outside, on which there was less than the natural share. A Leyden phial cannot be charged when it is insulated, that is, when neither the inside nor the outside is connected with the earth, because as much of the electrical fluid must be thrown off from one side, as is received on the other; and if it is unconnected with the earth, it has no means of parting with any of its natural quantity from one side, and of course cannot receive a redundance on the other.

A jar is said to be *positively* electrified, if when the inside

receives the fluid from the conductor, &c. the outside is connected with the earth. It is said to be *negatively* electrified, when the outside receives the fluid from the conductor, and the inside is made to communicate with the earth.

If one jar charged negatively be brought in contact with, or near another charged positively, both jars will be discharged with a violent explosion, provided the jars are highly charged.

The passage of the electric fluid, from one side of a charged jar to the other, is apparently instantaneous, whatever be the length of the metallic, or other good conductor. If a number of persons join hands, and make part of the circuit of communication, the fluid will pass, and the shock be felt instantaneously through the arms of them all. In this case, the person at one end of the circuit must touch the outside of the jar, or some conducting substance that communicates with it, and the person at the other end must connect himself with the inside by touching the knob A.

If the circuit be continuous, the passage of the fluid will be invisible; if it be interrupted, the fluid becomes visible; and if resisted in its passage, it will leave an impression upon the intermediate and resisting bodies. If the fluid pass from one side of a jar to the other, through a chain, it will be visible between the links of the chain. If it be interrupted by several folds of paper, a perforation will be made through them all. If spirit of wine or gunpowder be made part of the circuit, it will be inflamed.

Of the electrical Battery. The force of the electrical charge may be increased, by augmenting the surface of the coated glass: that is, if several coated jars are used, in the same experiment, instead of one. In this case, the outsides of all the jars must communicate with one another, and so must the insides. Jars so arranged, whatever be their number, form an electrical *battery*. By means of a battery of a considerable size, the most important effects may be readily produced; fine wire may be fused, and small animals may be killed: hence, and from other undeniable experiments, it is

inferred, that the electric fluid and lightning are the same substance. Their properties and effects are the same. Flashes of lightning form irregular lines in the air; the electric spark, when strong, has the same kind of appearance. Lightning seizes upon the highest and most pointed objects; takes in its course the best conductors; sets fire to bodies; melts metals, &c.; kills in an instant the strongest animals; in which, and other particulars, it agrees with the phenomena of the electric fluid. Lightning also being brought from the clouds by an electrical apparatus, will exhibit all the appearances of the electric fluid.

The atmosphere is always in a state of electrization, sometimes negatively, but generally with positive electricity. In calm and serene weather, the electricity is positive, and the quantity is usually in proportion to the quantity of moisture in the air. Hail is always accompanied with electricity, and rain generally so. Low and thick fogs are strongly electrical. In summer, the electricity of the atmosphere is very weak, it grows stronger at sun-rise, and increases in strength till sun-set, when it again becomes weaker. A strong electricity often rises with the dew, particularly if the season be cold, the sky clear, and there be but little wind.

The following works on the subject of Electricity, may be mentioned as deserving the reader's notice.

Dr. Priestley's "Introduction to the Study of Electricity" is excellent for the uninitiated, but it is out of print, and the plates being lost, is not likely to be brought again before the public. As a substitute for this, the sixth volume of the "Scientific Dialogues" may be fitly used, in which are accumulated all the common and most interesting experiments; which, being repeated, with the directions given for their performance, the young electrician will afterwards find no difficulty in the pursuit of electrical knowledge in all its branches.

"An Essay on Electricity," &c. by George Adams, with Improvements by W. Jones, is a valuable compilation of all the material facts and experiments in this branch of science.

"A complete Treatise on Electricity in Theory and Practice," in three vols. 8vo. by Tiberius Cavallo, is a very proper work for those who are desirous of an extensive knowledge in every department of Electricity. The first volume treats of the laws and theory of electricity, and contains a full detail of the practical branches of the science. In the second, the author describes a number of new experiments, enters rather at large on the subject of medical electricity, which was in much more estimation twenty years ago than it is at present, and treats of the electrical properties of the torpedo, &c. In the third volume will be found, among other interesting subjects, a particular account of what was then deemed *animal electricity*, but now denominated Galvanism.

"The History and present State of Electricity, by Joseph Priestley, LL.D. F.R.S." &c., will always be a stock book, valuable as a work of reference, and highly interesting to those who would wish to trace the progress of the science to that advanced period in which it was when the author wrote. A continuation of this work, for which there are ample materials, would, it is imagined, be very acceptable to the public.

"Principles of Electricity, containing divers new Theorems and Experiments, &c. by Charles Viscount Mahon." This work was published on the occasion of the dispute which, more than thirty years ago, engaged the attention of electricians, respecting the best mode of securing buildings from the effects of lightning. His Lordship was the advocate of pointed conductors, which have now generally obtained the preference. In this treatise is a regular dissertation on the nature of the "Returning-stroke," by the effects of which, the noble author contends, that men and other animals may be killed, and buildings damaged and destroyed, when the thunder-cloud, from which the mischief proceeds, is at the distance of several miles from the spot where such persons or buildings are situated. This theory, Lord Mahon (now Earl Stanhope) regarded as completely established by the death of James Lauder, in Scotland, which happened some time after the theory had been advanced. See Phil. Trans. Vol. lxxvii.

"Practical Electricity and Galvanism, by John Cuthbertson, Philosophical Instrument-maker," contains an extensive series of interesting experiments.

"Elements of Electricity and Electro-Chemistry, by George Singer;" "Miscellaneous Experiments and Remarks on Electricity, &c. with a description of an Electrometer, on a new Construction, by A. Brook;" and "New Experiments on Electricity, wherein the Causes of Thunder and Lightning are explained, &c. also a Description of a Doubler of Electricity, and the most sensible Electrometer, &c. by the Rev. A. Bennet, F.R.S." are excellent treatises, and may be consulted with pleasure and improvement by the student in electricity. Besides the authors already mentioned, the adept, and indeed those who have made any progress in the science, will recollect the names of Beccaria, Watson, Wilson, Read, Dalton, and Lyon, who have written on, and most of them added many new facts to the science. Nor can the name of the celebrated Benjamin Franklin be unnoticed, who, though he has left no regular treatise on the subject, made the most important and interesting discoveries in this branch of science; and did by his assiduity, and writings, though given through the medium of the Transactions of learned Societies, more than any other individual, to bring it to that perfection in which it at present exists. By Signior Beccaria, who dedicates to Franklin, his "Treatise upon artificial Electricity," he is considered as the father of the science. "It is you," says the learned Italian, "who have disarmed the thunder of its terrors; and your daring genius has even taught the fire of heaven, that was formerly looked on as the weapon of omnipotence, to obey your voice."

GALVANISM.

THE science of *Galvanism*, or as it is now generally denominated *Voltaism*, is only of twenty-five years' standing. It took its first name from Galvani, a professor at Bologna, who prosecuted the subject to a certain extent; but it now, under the more general name of Voltaism, comprises

all those electrical phenomena, that arise from the chemical agency of certain metals with different fluids.

Galvani, by accident, as he was dissecting or cutting up a frog, discovered that the common electricity had the property of producing muscular contractions in the limbs of animals a considerable time after death. He afterwards found that, by the mere agency of a metallic substance, where he had no reason to suspect the presence of electricity, the limbs of a recently killed frog were convulsed; and having ascertained the fact by a number of experiments, he, in the course of his inquiries, found that the convulsions or contractions were produced only when dissimilar metals were employed.

It was now inferred that electricity is not only produced by the friction of bodies, as has been already described, but even by the mere contact of certain substances. At the same time it was admitted, that these substances must have some chemical agency or action upon each other, and that the effect produced seems to be proportionate to the degree of chemical action. The following well known facts were now supposed to be explained by this infant science.

Porter, taken from a pewter pot, has always been held, by connoisseurs in that liquor, to be better than when taken from china and glass; this was now said to arise from a certain decomposition affected by means of the liquor in the vessel, the pewter, and the saliva on the under lip coming in contact with the metal.

Pure mercury retains its metallic splendor a long time, but its amalgam with tin, &c. is almost immediately oxydated or tarnished.

Inscriptions of very ancient date on pure lead, have been found in a perfect state, while others of modern times, made on compound metals, are corroded, and scarcely legible. Works of metal, whose parts are soldered together by means of other metallic substances, soon tarnish, or are oxydated about the places in which the different metals are joined. So likewise is the copper on ships, which is fastened on by means of iron

nails. Zinc also may be kept a long time under water with scarcely any change; but if a piece of silver touch the zinc while under water, there will be, very soon, a sensible oxydation

Take a piece of zinc, and place it under the tongue, and lay a piece of silver, as a half-crown, upon it, and no particular taste will be observed; but bring the outer edges of the metals into contact, and a very disagreeable taste will be perceived, which is said to arise from the decomposition of the saliva, a watery fluid. The same thing may be noticed with a guinea and a piece of charcoal.

These facts have been thus explained, and the theory generally admitted: the *conductors* of electricity, however they may differ from each other in their conducting powers, may be divided into two classes. The *first* class, which are denominated the *dry* and more perfect conductors, consist of metallic substances and charcoal: the *second* class, called also imperfect conductors, are water and other oxydating fluids. From these, or some of them, all *Galvanic Circles*, as they are named, are formed.

The simplest circles or combinations must consist of three conductors of different classes, viz. one conductor of one class, and two different conductors of the other class. When two of these substances are of the first class, and one of the second, as was the case with the zinc, the silver, and saliva, the combination or circle, is of the first order, that is, the most powerful: but otherwise, as in the case of the porter drunk out of pewter, the circle is of the second order, that is, the least powerful. In a simple galvanic circle, the two bodies of the same class must touch each other in one or more points, at the same time that they are connected, at other points, by the body of the other class.

The nerves of animals appear to be affected by smaller quantities of electricity than any other substances; hence prepared limbs of animals were for a considerable time much employed for ascertaining the production of electricity by

simple contact. If electricity be made to pass through the prepared limb by the immediate contact of the electrified body, a much smaller quantity of it is sufficient to occasion the contractions, than when it is made to pass from one conductor to another, at a certain distance from the prepared limb; and these contractions are much stronger, when the electricity passes through a nerve to the muscles, than through any other part. Similar effects may be produced in the prepared animal, without any apparent aid of electricity, merely by making a communication between the nerves and muscles by a conducting substance. But if the communication between the nerve and the muscle be formed by substances which are non-conductors of electricity, as glass, sealing-wax, &c. then no contractions take place.

The conducting substances, which answer best for this purpose, are silver and zinc; but silver and tin, or silver and copper, will answer very well. If part of the nerve of a prepared limb be wrapped up in a piece of tin-foil, or be laid upon zinc, and a piece of silver be laid with one end on the muscle, and with the other upon the tin or zinc, the contractions of the limb will be violent.

The two metals may be placed either in contact with the preparation, or in any other part of the circuit, which may be completed by means of other conductors, as water. Let two wine-glasses, nearly full of water, be near to, but not actually touching each other. Put the prepared thigh and leg of a frog into the water of one glass, and laying the nerve over the edges of the two glasses, let the tin-foil, which is wrapped round it, touch the water of the other glass. If now a communication be formed between the water in the two glasses, by means of silver, or by putting the fingers of one hand into the water of the glass that contains the leg, and holding a piece of silver in the other, the coating of the nerves being touched with it, the prepared leg will be so much excited as sometimes actually to jump out of the glass. These contractions may be excited in living as well as in dead animals.

Take, for instance, a live flounder, and having made it dry, put it in a pewter plate, or upon a large piece of tin-foil, and place a piece of silver on its back; then with one end of a piece of metal touch the pewter-plate, and apply the other extremity of the metal to the silver, and contractions will immediately ensue.

Experiments of a similar kind, which are recorded by Aldani and others, were made upon many different kinds of animals, and even upon persons who had suffered death from the hands of the executioner; the actions produced were ascribed to a principle of electricity, and the science, then only in its infancy, thus limited to general experiments on the animal frame, was denominated, after its earliest discoverer, Galvanism.

Galvani explained the phenomenon, by conceiving the muscles to resemble a charged Leyden phial, having electricity accumulated in the inside, while the outside was charged minus. The nerves he considered to be connected with the inside: when it was united with the outside by conductors, the surplus electricity was discharged, which caused the motions of the limb.

Signior Volta, the illustrious improver of this science, set out with the idea, contrary to that of Galvani, that the electricity did not belong to the animal, but to the different metals employed. Galvani was not likely to produce any greater effect than what could be obtained by two pieces of metal, because he believed the electricity to be in the animal. Volta was led to the discovery of the battery by combining a number of pieces of metal together, because he was persuaded that the electricity was in the metals or fluids employed. These repeated combinations obtained the name of Galvanic, or more properly, Voltaic batteries, and the science itself is usually denominated from the discoveries resulting from these batteries, *Voltaism.*

VOLTAISM.

The batteries of Volta are said to be of the first or second order, according as the simple combinations of which they consist, are of the first or second order. The batteries of the *first* order are composed of two perfect conductors, and one imperfect conductor, as zinc with gold, or silver, or copper, &c. and a solution of nitric acid in water.

The batteries of the *second* order, are composed of two imperfect conductors and one perfect conductor, as one metal with two fluids.

In plate IV. fig. 5, we have the representation of a voltaic battery. It consists of a number of pieces of silver, zinc, and flannel cloth, of equal sizes; the flannel is moistened with an oxydating fluid, and they are so arranged that the zinc, silver, and flannel may succeed each other in regular order, as often as the combinations are repeated. If the lower piece of metal is touched with one hand, and the upper one with the other, an electrical shock will be felt. The same experiment may be repeated till the metals become, in a measure, oxydated and unfit for action, when they must be taken down and cleaned.

In fig. 6 is a different kind of battery. In these four glasses, (and twenty or more might be used, in order that the effect might be more powerful), is a solution of salt and water: into each, except the two outer ones, is plunged a small plate of zinc, and another of silver; these communicate with each other by a thin wire, so fastened that the silver of the first glass is connected with the zinc of the second, the silver of the second with the zinc of the third, and so on. If one hand be now dipped into the first glass, and the other into the last, there will be made a communication between the zinc and silver, and a shock will be felt.

Another and more powerful kind of battery, consists of a trough of baked wood three inches deep, and as many in breadth, fig. 7. In the sides of this trough are grooves opposite to each

other, and about a quarter of an inch asunder. Into each pair of grooves is put a plate of zinc, and another of silver, and they are cemented in such a manner as to prevent a communication between the different cells. The cells are now filled with some oxydating fluid, and the battery is complete; if a communication be made with the two hands between the two end cells, a strong shock will be felt. With batteries of this kind, only much increased in size, a number of curious and interesting experiments may be made. Wire may be melted, and gunpowder, gold and silver leaf, &c., may be inflamed. Water has also been decomposed by means of batteries of this kind; let AB, fig. 8, represent a glass tube filled with distilled water, having a cork at each end. A and B are two pieces of brass wire, which are brought within about an inch of one another in the tube, and the other ends are carried to the battery, viz. A to the positive and B to the negative end; when, if the battery be in full action, and the circuit be uninterrupted, a stream of bubbles will proceed from the wire B, and ascend to the upper part of the tube: these bubbles are hydrogen gas, or inflammable air, and they no doubt proceed from the water, being one of the component parts of it. The experiment, as described in several books, may be varied, and both the oxygen and hydrogen gas collected separately.

In the hands of Sir Humphry Davy, the Voltaic battery has achieved the most important and interesting discoveries, which the student in natural philosophy will take much pleasure in examining for himself in the papers of that great chemist, to be found in the different volumes of the Transactions of the Royal Society since the year 1806; in the course of which he proves most satisfactorily, that the voltaic energy has the property of decomposing compound substances, provided the battery be sufficiently powerful, and the constituents of such compound bodies will range themselves about the wires that pass from the extremities of the batteries, according to the following law: oxygen and acids arrange themselves about the positive wire, being themselves possessed of negative qualities: while hydro-

gen, alkalies, earths, and metals, being possessed of positive qualities, are attracted by the negative wire.

Hence it is inferred, that when two substances are chemically combined, they are in different states of electricity; and the more completely opposite these states, the more intimately will they unite. Thūs water is an instance of the complete chemical combination of the negative oxygen and positive hydrogen gases: and to separate the two constituents from each other, we have, as we have seen, only to bring them to the same electrical state, and this effect the voltaic energy produces; which fact is supposed to prove that chemical affinity, that most important law in nature, is nothing more than the attraction which exists between bodies in different states of electricity. See *Chemistry*.

The decomposition of the fixed alkalies, of the alkaline earths, of boracic acid, and other substances, of which very interesting and detailed accounts are given in the papers above referred to, was discovered by Sir Humphry Davy, and the result of his original discovery. "These facts, though very striking and important, are not to be compared, in point of value, to his original discovery of the *principle*, the decomposing power of Voltaism, which has made us acquainted with a new energy in nature, and put into our possession a much more efficient chemical agent than any with which we were before acquainted. This is the discovery which does so much honour to Sir Humphry Davy, and has put him on a level with the small number of individuals who have been fortunate enough to lay open to the world a new law of nature."

The first grand experiment upon the igniting powers of *large* voltaic *plates* formed into batteries, was made by the French chemists, Fourcroy, Vauquelin, and Thenard; but a much larger combination for exhibiting the effects of an extensive surface was constructed by Mr. Children; it consisted of a battery of twenty double plates four feet by two, of which the whole surfaces are exposed, in a wooden trough, in cells covered with cement, to the action of diluted acids. The

most magnificent battery that yet exists, was constructed at the expense of some individuals, at the laboratory of the Royal Institution, of which the whole surface exposed to the action of the oxydating fluid, is equal to 128,000 square inches: some of the effects of this battery have been thus described:

When pieces of charcoal about an inch long and one-sixth of an inch in diameter, were brought near each other (within the thirtieth or fortieth part of an inch), a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness; and by withdrawing the points from each other, a constant discharge took place through the heated air, in a space equal at least to four inches, producing a most brilliant ascending arch of light, broad, and conical in form, in the middle. When any substance was introduced into this arch, it instantly became ignited; platina melted as readily in it, as wax in the flame of a common candle; quartz, the sapphire, magnesia, lime, all entered into fusion; fragments of diamond, and points of charcoal and plumbago, rapidly disappeared, and seemed to evaporate in it, even when the connexion was made in a receiver exhausted by the air-pump, but there was no evidence of their having previously undergone fusion.

When the communication between the points positively and negatively electrified, was made in air, rarefied in the receiver of the air-pump, the distance at which the discharge took place increased, as the exhaustion was made; and when the atmosphere in the vessel supported only one-fourth of an inch of mercury in the barometrical gage, the sparks passed through a space of nearly half an inch; and by withdrawing the points from each other, the discharge was made through six or seven inches, producing a most beautiful coruscation of purple light, the charcoal became intensely ignited, and some platina wire attached to it, fused with brilliant scintillations, and fell in large globules upon the plate of the pump. All the phenomena of chemical changes were produced with intense rapidity by this combination. When the points of charcoal were brought near

each other in non-conducting fluids, such as oils, ether, and oxymuriatic compound, brilliant sparks occurred, and elastic matter was rapidly generated; and such was the intensity of the electricity, that sparks were produced, even in good imperfect conductors, such as the nitric and sulphuric acids.

Of the writers on this branch of science, there is little to be said: it is even yet too much in its infancy to have admitted of a regular elementary treatise; but independently of the third volume of Cavallo's Electricity, to which we have before referred, the student should be informed of the following works.

"Experiments on Animal Electricity, with their Application to Physiology, &c. by Eusebius Valli, M.D."

"Experiments and Observations relative to the Influence lately discovered by M. Galvani, commonly called Animal Electricity, by R. Fowler."

"An Account of the late Improvements in Galvanism, with a set of curious Experiments, &c. by John Aldini." These tracts contain many judicious, well-conducted and highly interesting experiments; but they relate wholly to Galvanism, and were all written prior to the discoveries since made by means of Volta's batteries. The best accounts of these discoveries will be found in the several papers in the Philosophical Transactions already referred to, and in Sir Humphry Davy's own work on Chemistry. There is, however, an excellent article on this part of the science under the word GALVANISM in Dr. Rees's New Cyclopedia; and another, though on a smaller scale, in the Pantalogia, under the word VOLTAISM.

MAGNETISM.

THE natural magnet or loadstone is a hard mineral body of a dark-brown or blackish colour, and when examined, it is found to be an ore of iron. It is sometimes found in immense masses, especially in the iron mines of Sweden. The power by which it is influenced, and influences other bodies, and which is manifested by certain phenomena of attraction and repulsion, is called the magnetic power: and the

science, in which phenomena of this kind are classified and reduced to certain laws, is called magnetism.

The attractive power of the magnet was known to the ancients, but its directive power to the north and south has been a much more modern discovery. This very singular fact was remarked by people in different countries about the same period, so that it is impossible to assign the discovery to any particular person or country. It was, however, made at the end of the thirteenth, or the commencement of the fourteenth century, and upon this directive power, depend the construction and use of the mariner's compass, which enables the seaman to guide his vessel over the trackless seas, and which guides miners in their subterranean excavations, and travellers in their journeys through deserts, and the wild and desolate sands of Africa.

The natural magnet has the quality of communicating its own attractive and repulsive properties to iron and steel, so that when bars of steel are prepared by the magnet, they themselves become magnets, and are denominated *artificial* magnets; and what is very singular, these artificial magnets can be made much stronger and more powerful than the natural ones from which they are formed; and being more convenient, they are universally used in all practical purposes instead of the magnet itself.

Properties of the Magnet. The following are the leading and characteristic properties of a magnet, so that no substance can be properly denominated a magnet that is not possessed of them all. 1. The magnet attracts iron and steel. 2. A magnet, if left at liberty, that is, placed, for instance, on a cork, and put on the surface of water, so that it can move freely in every direction, will point towards the poles of the earth, or very nearly so, and each end always points to the same pole. This is called the *polarity*, or directive power of the magnet. When the magnet places itself in this direction, it is said to *traverse*. 3. When the north pole of one magnet is

presented within a certain distance to the south pole of another, they will attract each other. But if a north pole of one be presented to the north pole of another, or a south to a south, they will repel each other. 4. The two poles of a magnet, left at liberty, do not lie in the same horizontal direction: one of them inclines toward the horizon, and of course the inclination of this causes an elevation of the other pole above it. This is called the inclination or dipping of the magnet. 5. Any magnet may, by the methods described by different authors, be made to impart those properties to iron or steel.

Magnetic Attraction and Repulsion. When a piece of iron is brought within a certain distance of one of the poles of a magnet, it is attracted by it, and adheres to it so as not to be separated but by force. The attraction is mutual, the iron attracting the magnet, as well as the magnet attracting the iron: for if the magnet and the iron be put on two separate pieces of cork floating upon water, it will be seen that the iron moves towards the magnet as well as the magnet towards the iron. This attraction is strongest at the poles of a magnet, and diminishes in proportion to the distance of any part from the poles, so that in the centre point between the poles there is no sign of attraction whatever.

Two magnets put in the same situation as the magnet and iron, will, if the poles of the same name be presented to each other, repel each other; but if a north and south pole be presented, the same kind of attraction will be visible. Nor will this attraction and repulsion be in the least diminished, or any way affected by the interposition of any kind of bodies except iron. Thus, if the two magnets, or the magnet and iron, be brought together within the distance in which action will take place, and a slip of wood or other substance be interposed between them, it will not prevent them from coming as close together as the interposing body will admit.

Iron is more easily rendered magnetic than steel, but it does not retain the magnetic properties so long. The properties of

the magnet are not affected either by the presence or by the absence of the air; but heat weakens its power, and a white heat destroys it.

There seems to be a similarity between magnetism and electricity; in proof of which the following experiment is given. Tie two pieces of soft iron wire, fig. 9, each to a separate thread, and let them hang freely from a hook *x*; if now the marked or north end of a magnet bar be brought just under them, the wires will repel each other, which is undoubtedly occasioned by both bodies possessing the same kind of power. The same thing would have occurred had the south pole of the magnet been presented instead of the north.

Strew on a sheet of paper, some iron filings, and lay a small magnet among them; shake the table a little, and the filings will arrange themselves in the way represented in Pl. IV. fig. 10.

If iron filings are shaken through a gauze sieve upon a paper that covers a bar magnet, the filings themselves will become magnets, and will be arranged in curved lines.

The Polarity of the Magnet. Every magnet, as has been seen, has a north and south pole, which are at its opposite ends; and a line, drawn from one to the other, passes through the centre of the magnet; the line itself is called the axis of the magnet; and a line formed, or supposed to be formed all round the surface, by a plane which divides the axis into two equal parts, and is perpendicular to it, is called the equator of the magnet.

It is the *polarity* of the magnet that renders it so useful to navigators; for when a magnet is kept suspended freely, the pilot, by looking at its position, can steer his course in any required direction. Thus, if a vessel is to be steered towards a certain place, which lies exactly west of that from which it sets out, the pilot must direct it so, that its course may be always at right angles with the direction of the magnetic needle of his compass, keeping the north end of the magnet on the right hand side, and, of course, the south end on the left hand side of the vessel; for as the needle points north and

south, and the direction is east and west, the intended course of the vessel is exactly perpendicular to the position of the magnet.

An artificial magnet fitted up in a proper box, for the purpose of guiding the direction of a traveller by sea or land, is called the magnetic needle; and the whole together is called the mariner's compass, fig. 11.

It must be observed, that though the north pole of the magnet, in every part of the world, when at liberty, points to the northern parts, and the south pole towards the southern parts, yet it seldom points exactly towards the poles of the earth. The angle in which it deviates from due north and south, is called the *angle of declination*, or *the variation of the compass*; and the declination is said to be east and west, according as the north pole of the needle is eastward or westward of the astronomical meridian of the place. This declination is different in different parts of the world, and is continually varying in the same part of the world. When the variation was first observed, the north pole of the needle declined eastward of the meridian of London, but it has since that time been changing continually towards the west, so that in 1657, the needle pointed due north and south. At present its declination is about 24° westward.

The mariner's compass generally used on board of ships, consists of three parts: the box, the card or fly, and the needle. The box, which contains the card and needle, is circular, and made of wood, brass, or copper; and is suspended within a square wooden box, by means of two concentric circles called gimbalds, so fixed by cross axes to the two boxes, that the inner one, or compass-box, shall always retain a horizontal position in all motions of the ship, while the outer or square box is fixed with respect to the ship. The compass-box is covered with a pane of glass, in order that the motion of the card may not be disturbed by the wind. The card is only a circular piece of paper, which is fastened upon the needle, and moves with it. Sometimes there is a

slender rim of brass, which is fastened to the extremities of the needle, and serves to keep the card stretched. The outer edge of this card is divided into 360 equal parts or degrees, and within the circle of those divisions, it is again divided into 32 equal parts or arcs, which are called points of the compass, or rhumbs, each of which is subdivided into quarters. The initial letters, N. N, E, &c. are annexed to those rhumbs, to denote the north, north east, &c. The magnetic needle is a slender bar of hardened steel, having a hole in the middle, to which a conical piece of agate is adapted. The apex of this hollow cap rests upon the point of a pin which is fixed in the centre of the box, and upon which the needle, being properly balanced, turns very nimbly. For common purposes the needles have a conical perforation made in the steel itself, or in a piece of brass, which is fastened in the middle of the needle. To prevent the dip which attaches to every magnetised needle, a small weight is put on the apparently lighter side, to balance it.

The following works on the science of Magnetism are the most deserving of the attention of the student.

"A Treatise on Magnetism in Theory and Practice," &c. by Tiberius Cavallo, is unquestionably the best work on this subject. The author, by collecting from former writers whatever is curious and useful, has exhibited in a perspicuous and scientific manner, a comprehensive view of the present state of knowledge, relative to magnetism; and by the arrangement which he has adopted, the reader will be led from the simplest to the most intricate part of the subject.

The volume is divided into four parts: in the *first* the laws of magnetism are clearly stated: the *second* contains the theory of magnetism: in the *third* is an account of practical magnetism, including a description of magnetical instruments: and the *fourth* is devoted to a set of new magnetical experiments, invented by Mr. Cavallo. To the second and third editions of this work, a supplement was added, containing several curious and useful papers, viz. An attempt to explain

the cause of the variations of the needle, by Dr. Lorimer—A description of a new variation compass—Remarks on the methods proposed for ascertaining the longitudes and latitudes of places, by means of magnetical instruments, &c.

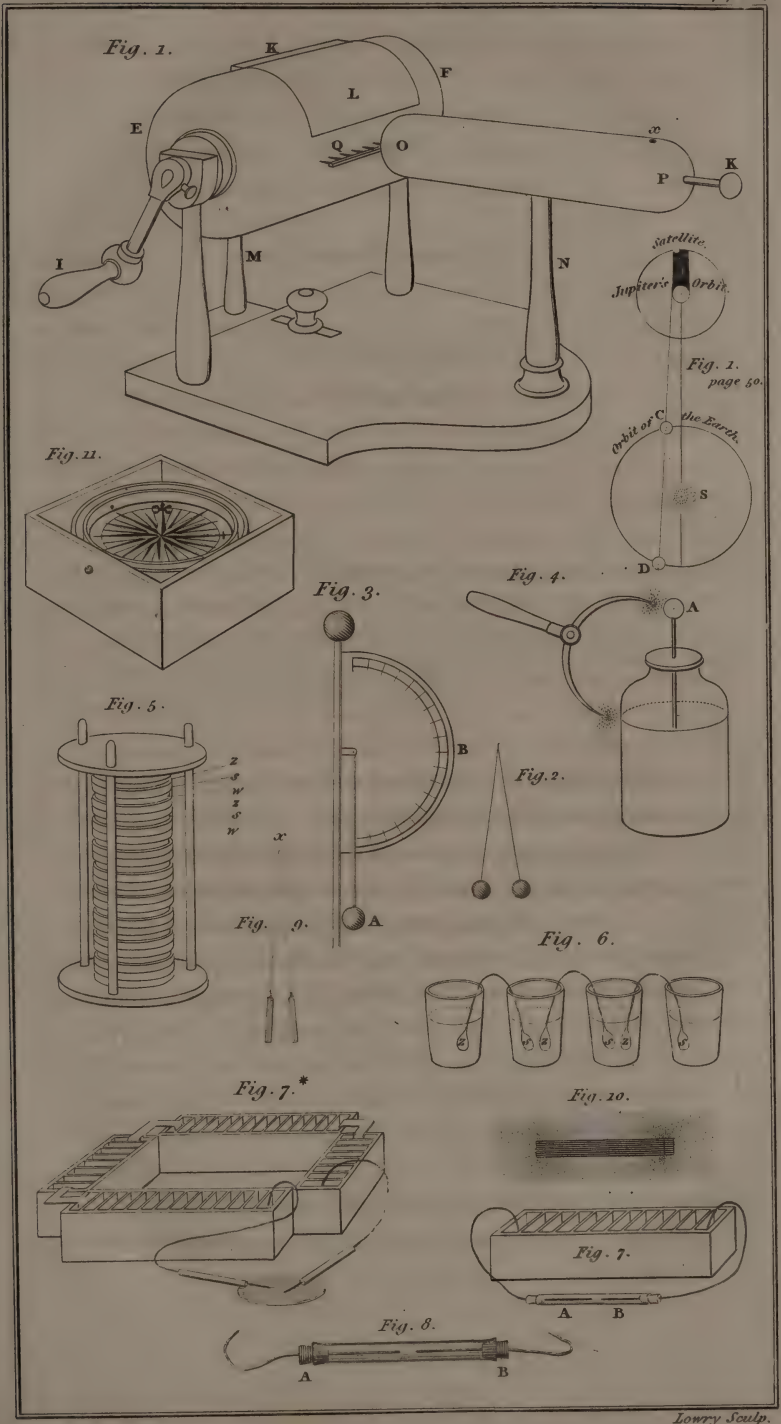
"A concise Essay on Magnetism, &c. by John Lorimer, M.D."

This is a much shorter work than that of Mr. Cavallo, but it is a very good treatise as far as it goes. An historical account of magnetism forms an introduction to the volume. The author quotes at length some curious verses of Guivot de Provins, cited by the famous Athanasius Kircher and others, which seem to prove that the use of the magnet, in forming a compass at sea, was known in the twelfth century, though commonly attributed to the beginning of the fourteenth. These verses exist in MS. in the National, or as it is now called, the Royal Library at Paris.

"The Magnetic Atlas, or Variation Charts of the whole Terraqueous Globe, comprising a System of the Variation and Dip of the Needle; by which, Observations being truly made, the Longitude may be ascertained: by John Churchman."

The charts in this atlas, if the principles of their construction were correct, would be of vast importance to navigation, but the author has probably been much too sanguine in his expectations.

There is an excellent article on this subject in the second volume of Hauy's Elementary Treatise on Natural Philosophy, p. 58-137; and since the publication of this treatise, a memoir has been presented to the French National Institute, "On the variations of the Terrestrial Magnetism in different Latitudes."



Lowry Sculp.

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CHAP. V.

NATURAL PHILOSOPHY,

Continued.

Astronomy, sketch of the history of—appearances of the heavenly bodies—division of the fixed stars—constellations—Speculations of Dr. Herschel—Solar System—Sun—Planets: Mercury—Venus—The Earth—Mars—Ceres—Pallas—Juno—Vesta—Jupiter—Saturn—Georgium Sidus—Satellites—Moon.

Most authors ascribe the origin of Astronomy, either to Chaldea or Egypt. The Chaldeans boasted of their temple or tower of Belus, and of Zoroaster, whom they placed 5000 years before the destruction of Troy; and the Egyptians speak of their colleges, in which astronomy was taught, and of the monument of Oxymandyas, in which it is said there was a golden circle of 365 cubits in circumference, divided into 365 parts, corresponding to the number of days in the year. There are, on the page of history, unquestionable facts, which prove that both the Chaldeans and Egyptians were acquainted with many of the principles of Astronomical science, at a very early period.

From Chaldea and Egypt, this science passed into Phœnicia, the inhabitants of which country, applied it to the purposes

of navigation, steering their course by the north-polar star; and hence they became masters of the sea, and of almost all the commerce of the world. The Greeks, it is probable, derived their astronomical knowledge chiefly from the Egyptians and Phœnicians, by means of several of their countrymen who visited these nations for the purpose of learning the different sciences. Sir Isaac Newton supposes, that most of the constellations were invented about the time of the Argonautic expedition, though other writers imagine they can trace this species of knowledge to a much earlier period. Several of the constellations are mentioned by Hesiod and Homer, the two most ancient of the Greek writers, who flourished about nine centuries before the birth of Christ. Their knowledge was greatly improved by Thales, who flourished three hundred years later: this philosopher was followed by Anaximander, Anaxagoras, and especially Pythagoras, who lived five centuries and a half before the Christian æra, and taught the true system of the world, as it has been demonstrated by Copernicus and Newton in later times.

Eratosthenes, about two hundred and fifty years before the birth of Christ, measured the earth by means of a gnomon: he also determined the distance between the tropics, and made the obliquity of the ecliptic to be 23° 51′. Archimedes likewise was a great cultivator of astronomy, as well as of geometry and mechanics: he determined the distances of the planets, and is said to have constructed a sort of planetarium, which represented the phenomena and motions of the heavenly bodies. Hipparchus, who flourished a century later than Eratosthenes, was the first person who applied himself to every part of Astronomy: he discovered that the orbits of the planets are not circular, but elliptic, that the moon moved slower in one part of her orbit than in another, and many other facts, of which his predecessors had no idea. But the chief work of this philosopher is his catalogue of fixed stars, to the number of more than a thousand, with their longitudes,

latitudes, and apparent magnitudes. From Hipparchus to Ptolemy, who flourished in the first century of the Christian æra, little or no progress is to be traced in the study of astronomy. Ptolemy made a system of his own, which, though proved in after-times to be completely erroneous, was implicitly followed for many ages by all nations. He compiled a great work entitled the Almagest, which contained the observations and collections of Hipparchus and his other predecessors in astronomy; on which account it has always been in the highest estimation with the professors of that science. This work most fortunately escaped the horrible conflagration of the Alexandrian library, was translated out of Greek into Arabic in the year 827, and from that language into the Latin in 1230.

Considerable improvements were made in astronomy by the Arabians; among whom may be mentioned Arzachel, a Moor of Spain, who observed the obliquity of the ecliptic, and greatly improved Trigonometry; and Alhazen, his contemporary, who wrote upon the twilight, the phenomenon of the horizontal moon, and who first demonstrated the importance of the theory of Refractions in astronomy. By the settlement of the Moors in Spain, the sciences in general were introduced into Europe; from which period they have continued to improve, and to be communicated from one people to another, to the present time, when astronomy and all the sciences have arrived at a very eminent degree of perfection. In this outline, the names of very few of the promoters of astronomy can be mentioned: in the selection, Nicolaus Copernicus must not be omitted. Early in the sixteenth century he conceived doubts respecting the Ptolemaic system, that made the earth a centre, round which the sun and planets revolved; and suspected that the sun himself must be the central body, which gave motion, as well as light and heat, to the planets. To confirm his theory, he made the most diligent observations, formed new tables, and at length, in 1530, completed a work containing these observations, and a renovation of the true

system of the universe, in which the planets are proved to be bodies revolving about the sun. This was the system of Pythagoras of old. Tycho Brahè, a noble Dane, attempted to improve upon the Copernican system; but his account of the planetary motions was involved, and very shortly fell to the ground. The labours of Tycho were, however, very important to the science of astronomy, although his system was the work of a fertile imagination only. He observed the great conjunction of Jupiter and Saturn, and he constructed, or caused to be constructed many much improved astronomical instruments. He discovered, in 1571, a new star in the chair of Cassiopeia; which induced him, like Hipparchus on a similar occasion, to make a catalogue of stars. Kepler was the next great improver of the astronomical science: he discovered several of the true laws of nature, by which the motions of the heavenly bodies are regulated. He ascertained, to a certainty, that all the planets revolve about the sun, not in circular, but in elliptical orbits, having the sun in one of the foci of the ellipses:—that their motions are not equable, but varying quicker or slower, as they are nearer to, or farther from the sun:—that the areas, described by an imaginary line drawn from the sun to the planets, are equal, in equal times, and of course proportional to the times of describing them. He also discovered by trials, that the cubes of the mean distances of the planets from the sun, are in the same proportion as the squares of the periodical times in which they revolve about the sun.

The beginning of the seventeenth century was distinguished by the invention of telescopes, and the application of them to astronomical observations. The more distinguished early observations with the telescope were made by Galileo, Huygens, and Cassini. Galileo is said to have manufactured with his own hands the telescopes with which were discovered the inequalities of the moon's surface, Jupiter's satellites, the ring of Saturn, and the spots on the surface of the sun, by means of which he discovered the revolution of that luminary round its axis. Hevelius furnished a catalogue of fixed stars

more complete than that of Tycho. Huygens and Cassini discovered the satellites of Saturn, and his ring.

The illustrious Newton first demonstrated from physical considerations, the laws by which the motions of the heavenly bodies are regulated. He taught upon mathematical principles, whence arose that constant and regular proportion observed both by the primary and secondary planets, in their revolutions about their central bodies.

Mr. Flamsteed was appointed the first astronomer royal at Greenwich, in 1675. He kept an almost perpetual watch, for the space of forty-four years, on all the celestial phenomena, viz. on the sun, the planets, the moon, and fixed stars, of all which he gave improved theories and tables, and he formed a catalogue of three thousand stars, with their places, to the year 1689.

In 1719, Mr. Flamsteed was succeeded by Dr. Halley, who gave the world the astronomy of comets, and a catalogue of stars in the southern hemisphere. On the death of Halley, in 1742, he was succeeded by Bradley, as astronomer royal, who, in addition to the other benefits which he conferred on science, discovered the aberration of light, and the nutation of the earth's axis. This astronomer was succeeded, in 1762, by Mr. Bliss, who did not retain the office many years, and was followed by Dr. Maskelyne, who had, in the year 1761, been sent by the Royal Society at a very early age, to the island of St. Helena, to observe the transit of Venus over the sun, and the parallax of the star Sirius. The labours of Dr. Maskelyne through a long course of years, are highly estimated by all those who are capable of appreciating his merit.

The discoveries of Herschel, Piazzi, Harding, and Olbers, form a new æra in astronomy. The former of these gentlemen, by his great skill in the construction of large specula, has made telescopes which have opened new views of the heavens, and unfolded scenes, which cannot fail to excite our wonder, admiration, and reverence of the Creator. In March, 1781, he discovered a new primary planet, named by himself, in honour of

his patron, the present king, the Georgium Sidus; but called by foreign astronomers, the Herschel, or the Uranus. He also discovered the six satellites which accompany this planet, and the two additional satellites that revolve about the planet Saturn.

M. Piazzi, astronomer-royal at Palermo, discovered, on the 1st of January, 1801, another planetary body, moving between the orbits of Mars and Jupiter: this is named the Ceres Ferdinandea. Another small planetary body was discovered by Dr. Olbers, on the 28th of March, 1802, which has been named the Pallas, and is about the same distance from the sun as Ceres, their orbits intersecting each other. Two other small planets have been since discovered, whose orbits are likewise between the orbits of Mars and Jupiter; of these, one was first seen in September, 1804, by M. Harding, which was named Juno: the other was discovered by Dr. Olbers in 1807, and is known by the name of Vesta. Such is a brief sketch of the history of astronomy brought down to the present period.

Heavenly Bodies. To the uninformed spectator, the earth appears an extended plain, round which, once in twenty-four hours, the sun and stars seem to revolve. In the morning the sun appears to rise in the eastern side of the heavens, to ascend to a certain height; and in the evening to descend towards the west, where it is lost. The stars seem to follow the same course, which is repeated daily, and without intermission. The points of the sea, or earth, which limit our view, constitute the horizon, being the place where the heavenly bodies seem to rise and set.

The sun and moon, the bodies with which we are more particularly concerned, appear to us to be the largest of the heavenly bodies. But from their apparent, we do not determine their real magnitudes. It is however of some importance to know how to estimate the apparent magnitudes of the heavenly bodies. We have seen in the chapter on optics, that all objects become visible by means of the luminous rays which

they transmit to us. When, for instance, we observe a celestial body, the rays of light proceeding from the opposite sides of its disc intersect in our eye a certain angle: the arc which measures this angle, determines the apparent magnitude, or at least the apparent diameter of the object. The permament or fixed stars do not offer such a regular disc, as to enable the eye or the best instruments to appreciate their diameters. These, however, constantly retain the same mutual arrangement and position: they rise and set constantly at the same points of the horizon, without being liable to any perceptible variations, excepting after very extensive intervals of time. Ten others only, besides the sun and moon, are exceptions to these rules: these indeed rise and set in the same manner as the stars rise and set; but on carefully remarking their positions, it will be perceived, at the end of some days, that they have changed their places: they no longer accompany the same stars, and no longer rise and set at the same points of the horizon. Hence they are called planets, or wandering stars, and in opposition to these, the others receive the name of fixed stars.

Besides the planets and fixed stars, there are seen occasionally in the heavens other stars, which at first appear very small, slightly luminous, and move among the stars very slowly: afterwards their brilliancy is increased, and their velocity is greatly augmented; they then gradually diminish and at length are totally lost from the sight. These wandering bodies are usually accompanied with a tail, which attends upon them during a part of their appearance: sometimes they are surrounded by something that has the appearance of hair, *coma*, hence they have obtained the name of comets.

The fixed stars shine no doubt with their own light, because they could not at the immense distances at which they are, be seen by reflected light. The light of the stars appears to the naked eye to be generally white; being too faint to excite the idea of any particular colour, but when it is concentrated by Dr. Herschel's large specula, it becomes, in various stars, of

various hues; and to those who have keen sight, some of the fixed stars, even to the unassisted eye, appear a little redder, and others of a bluish cast.

Without glasses, more than two thousand stars are never visible, and not more than one thousand at any one place and time; but when telescopes are used, the number of fixed stars appears to increase without any limits, except those which are occasioned by the imperfections of the instruments employed. Dr. Herschel has observed in the milky way above ten thousand stars in a small space in the heavens. Dr. Halley, and some other astronomers, have assumed that their number must be infinite, in order that they may remain at rest, by the opposition of attractions, acting in every possible direction.

The stars, on account of their apparently various magnitudes, have been distributed into several classes. Those which appear largest, are called stars of the first magnitude; the next to them in brilliancy, stars of the second magnitude; and so on to the sixth, which are the smallest that are visible to the naked eye. Those which cannot be distinguished by the naked eye, are called telescopic stars.

The ancients divided the starry sphere into particular constellations, or systems of stars, according as they lay near one another, so as to occupy those spaces which the figures of different sorts of animals would take up, if they were thus delineated. Those stars, which could not be brought into any particular constellation, are called unformed stars.

The division of the stars into constellations, or as they are sometimes called, asterisms, serves to distinguish them from one another, so that any particular star may be readily found in the heavens, by means of a celestial globe; on which the constellations are so delineated, as to put the most remarkable stars into such parts of the figures as are most easily distinguished. The number of the ancient constellations is 48, and upon globes of modern construction and of a large size, there are about 70: and on the better sort of globes are inserted Bayer's letters, the first, α, in the Greek alphabet

being put to the largest star, in each constellation; and the second, β, to the next in magnitude; and the third, γ, to the next; and so on: by which means every star is as easily found, as if a name were given to it.

There is another division of the heavens into three parts, viz. 1. The zodiac, so called, from the Greek word signifying an animal, because most of the constellations in it, which are twelve in number, have the names of animals, as *Aries*, the ram; *Taurus*, the bull; *Gemini*, the twins; *Cancer*, the crab; *Leo*, the lion; *Virgo*, the virgin; *Libra*, the balance; *Scorpio*, the scorpion; *Sagittarius*, the archer; *Capricornus*, the goat; *Aquarius*, the water-bearer; and *Pisces*, the fishes. The zodiac goes quite round the heavens, and is about sixteen degrees broad; so that it takes in the orbits of all the planets and the moon, excepting three of those smaller planetary bodies lately discovered, that revolve between Mars and Jupiter. Along the middle of this zone is an imaginary line, called the ecliptic, or that circle, which the sun appears, to an inhabitant of the earth, to describe, but which the earth really describes in its annual journey round the sun. 2. All that region of the heavens which is on the north side of the zodiac, containing twenty-one of the ancient constellations; and, 3. That on the south side, containing the other fifteen. The names of the constellations, and the number of stars observed in each of them by Ptolemy, Tycho, Hevelius, and Flamsteed, are given in most elementary books.

Besides the names of the constellations, the ancient Greeks gave particular names to some single stars, or small collections of stars: thus we have *Sirius*, the great dog-star; *Procyon*, the little dog; *Cor-Leonis*, *Arcturus*, &c. We have also the cluster of small stars in the neck of the bull, called the *Pleiades*; and five stars in the bull's face, denominated the *Hyades*.

The fixed stars are apparently dispersed in the heavens, without any regular order; but the attentive observer, especially if he possess instruments for the purpose, will perceive, in

many parts of the heavens, that a number of them are so much nearer together than the rest, as to form a cluster or nebula. The ancients had noticed some of the most conspicuous nebulæ, but Huygens first directed the attention of modern astronomers to the large one, situated in the constellation Orion. Dr. Herschel has of late years given catalogues of 2,500 nebulæ, many of which can be resolved into separated and individual stars by very high magnifying powers; but others appear to be more widely separated, and are individual stars of that particular nebula in which we are placed, and of which the marginal parts may be observed in the form of a lucid zone, which is called the milky way, being too distant to allow its constituent stars to be perceived by the naked eye.

Accurately speaking, the stars are not absolutely fixed with respect to each other; for several of them have particular motions, which have been discovered by a comparison of observations made at distant times. Arcturus has a progressive motion, amounting to more than two seconds in a year. Dr. Maskelyne discovered that out of thirty-six, whose places he ascertained with great precision, thirty-five had a proper motion of their own.

Respecting the arrangement of the fixed stars into different systems, we may give an abridged account of Dr. Herschel's speculations. He has divided them into a number of classes, to each of which he has assigned a distinct character. Some he supposes, like our sun, to be insulated stars beyond the reach of any sensible action of the gravitation of others; and around these alone he conceives that planets and comets revolve. Double stars in general, he imagines to be much nearer to each other, so as to be materially affected by their mutual gravitation, and only to preserve their distance by means of the centrifugal force derived from a revolution about their common centre of gravity: an opinion which, he thinks, is strongly supported by his own observations of some changes in the positions of double stars. Others again he supposes to be united in triple, quadruple, and still more compound systems. A fourth class consists of nebulæ like the milky way,

the clusters of stars being rounded, and appearing brightest in the middle. Groups of stars Dr. Herschel distinguishes from these by a want of apparent condensation about a centre of attraction; and clusters, by a still greater central compression. A seventh class includes such nebulæ as have not yet been resolved into stars, some of which Dr. Herschel supposes to be so remote, that the light emitted by them must actually have been two millions of years in travelling to our system. The nebulæ of another description resembling stars surrounded by a bar, or faint disc of light, a diffused milky nebulosity, apparently produced by some cause distinct from the immediate light of any stars, are the next in order; and Dr. Herschel has distinguished other more contracted nebulous appearances, in different states of condensation, into the classes of nebulous stars and planetary nebulæ, within and without bright central points.

Farther, it is fully ascertained, that some of the stars have periodical changes of brightness, which are supposed to arise either from the temporary interposition of opaque bodies revolving about them; or, still more probably, from a rotatory motion of their own, which brings, at certain periodical times, a less luminous part of the surface into our view. Thus, the star Algol, which is usually of the second magnitude, becomes at intervals of two days and twenty-one hours each, of the fourth magnitude only, and occupies seven hours in the gradual diminution and recovery of its light. Other irregular variations may possibly be occasioned by the appearance and disappearance of spots, occurring like the spots of the sun, without any determinate order, or assignable cause; and many stars have, in the course of ages, wholly disappeared, and sometimes have been again recovered: others have made their appearance for a short time, where no star had before been seen. Such a temporary star was observed by Hipparchus, 120 years before the Christian æra; and this circumstance suggested to him the propriety of making an accurate catalogue of all the stars, with their respective situations;

which is still extant, having been preserved by Ptolemy, who added 4 stars to the 1022 that it contained. In 1572, Cornelius Gemma discovered a new star in Cassiopeia, which was so bright as to be seen in the day-time, and gradually disappeared in sixteen months. Kepler, in 1604, observed a new star in Serpentarius, more brilliant than any other star or planet, and changing perpetually into all the colours of the rainbow, except when it was near the horizon: it continued visible for about a year. Many other new stars have also been observed at different times.

The Solar System consists of the Sun: seven primary planets; Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and the Herschel; eighteen secondary planets, the Earth's Moon, Jupiter's four satellites, Saturn's seven, and six belonging to the Herschel; and an uncertain number of comets. To these must be added the four small planetary bodies lately discovered revolving between the orbits of Mars and Jupiter; and named Ceres, Pallas, Juno, and Vesta.

Ptolemy supposed the earth to be perfectly at rest, and the sun, moon, planets, comets, and fixed stars to revolve about it every day; but that besides this diurnal motion, the sun, moon, planets, and comets, had a motion in respect to the fixed stars; and were situated, in respect to the earth, in the following order: the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn. The revolutions of these bodies he supposed to be made in circles about the earth placed a little out of the centre. This system will not solve the phases of Venus and Mercury, and, therefore, cannot be true.

The system received by the Egyptians was this: the earth was supposed immovable in the centre, about which revolved, in order, the Moon, Sun, Mars, Jupiter, and Saturn; and about the Sun revolved Mercury and Venus. This disposition will account for the phases of Mercury and Venus, but not for the apparent motions of Mars, Jupiter, and Saturn.

Another system was that of Tycho Brahè, a Danish nobleman, who was anxious to reconcile the appearances of nature

with some passages of the Scriptures, taken in their literal interpretation. In his system, the earth is placed immovable in the centre of the orbits of the sun and moon, without any rotation about its axis; but he made the sun the centre of the orbits of the other planets, which, therefore, revolved with the sun about the earth. Objections to this system are: the want of that simplicity, by which all the apparent motions may be solved; and the necessity of supposing that all the heavenly bodies revolve about the earth every day: also to suppose that a body should revolve in a circle about its centre without any central body, is physically impossible.

Some of Tycho's followers, seeing the absurdity of a diurnal revolution of the heavenly bodies about the earth, gave a rotatory motion to the earth; and this was called the Semi-Tychonic system.

The system which is now universally received, is called the Copernican. It was formerly taught by Pythagoras, 500 years before Christ; and afterwards rejected, till revived by Copernicus, in the sixteenth century. Here the sun is placed in the centre of the system, about which the planets revolve from west to east, in the following order: Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and the Herschel planet: beyond which, at immense distances, are placed the fixed stars. The moon revolves round the earth; and the earth turns about an axis. The other secondary planets move round their respective primaries from west to east at different distances, and in different periodical times.

According to this doctrine, the sun S, is the centre of the system; Mercury *a*, Venus *b*, the Earth *t*, Mars *e*, Jupiter *f*, and Saturn *h*, revolve in elliptical orbits round the sun; the moon *d*, revolves about the earth; and the satellites of Jupiter, Saturn, and the Herschel, revolve about their primaries, and the planes of their orbits are inclined to one another. See Plate V. fig. 1.

This doctrine, being admitted as true, will account for all the apparent motions, and other phenomena, of the heavenly bodies.

The *sun* is a spherical body, whose diameter is about 883,250 English miles, or 111 times larger than that of the earth, assuming the latter to be 7,950 miles; of course its magnitude is more than 1,367,631 times greater than that of the earth: but as the mean density of the earth is almost four times greater than that of the sun, the quantity of matter in the sun to that in the earth is about 340,000 : 1. In other words, the centre of gravity between the earth and sun, will be 340,000 times nearer the centre of the former body, than the centre of the latter, that is, within about 340 miles of the centre of the sun.

The sun affords to all the bodies that circulate about him, light and heat, and so much greater in proportion, as their distances are less from him; and he binds them to him by a certain influence, called, for want of a better term, the attraction of gravitation. The sun agrees with the fixed stars in the property of emitting light continually, and in retaining constantly its relative situation with very little variation. The sun, therefore, speaking generally, may be considered as a fixed star comparatively near to us, and the stars as suns at immense distances from us; hence it is inferred that the stars are possessed of gravitation, and of the other general properties of matter. They are supposed likewise to emit heat as well as light; and probably cherish the inhabitants of a multitude of planetary bodies revolving about them, as the earth and other planets revolve about our sun. The sun, like many of the fixed stars, has probably a progressive motion; which, from a comparison of the apparent motions of a great number of the stars, is supposed to be directed towards the constellation Hercules.

The sun revolves on its axis in about twenty-five days ten hours, from west to east, that is, supposing the order of the signs to be known, and a point in the sun to be opposite Aries, it moves towards Taurus. All the rotations of the different bodies, which compose the solar system, as far as they have been ascertained, are in the same direction. The time

and direction of the sun's rotation is ascertained by the change in the situation of the spots, which are usually visible on his disc. The spots are frequently observed to appear and disappear, and they are in the mean time liable to great variations, but are generally found about the same points of the sun's surface. On the different theories respecting the sun we cannot enter at large; but shall briefly observe, that Mr. King, in 1788, published a dissertation on that body, in which he advanced, that the real body of the sun is less than its apparent diameter: that we never discern the real body of the sun itself, except when we behold the spots: that the sun itself is inhabited as well as the earth and planets, and is not necessarily subject to burning heat; and that there is no violent elementary heat existing in the rays of the sun, but that they produce heat only when they come in contact with the planetary bodies. Since Mr. King advanced his theory, Dr. Herschel has given, in the Transactions of the Royal Society, his account of the nature of the sun. According to this able philosopher, the sun is a most magnificent habitable globe, surrounded with a double set of clouds. Those which are nearest its opaque body, are less bright, and more closely connected than those of the upper stratum, which form the apparently luminous globe we behold. This luminous external matter is of a phosphoric nature, having several accidental openings in it, through which we see the sun's body, or the more opaque clouds beneath. These openings form the spots we see. The sun, says the Doctor, in another paper, appears to be a very eminent, large, and lucid planet, evidently the first and only primary one belonging to our system. Its similarity to the other globes of the solar system, with regard to its solidity—its atmosphere—its surface diversified with mountains and vallies—its rotation on its axis—and the fall of heavy bodies towards its surface—leads us to suppose that it is most probably inhabited, like the rest of the planets, by beings whose organs are adapted to the nature of that vast globe.

This way of considering the sun is of the utmost importance

in its consequences. Since stars appear to be suns, and suns, according to the common opinion, are bodies that serve to enlighten, warm, and sustain a system of planets, we may have an idea of numberless globes that serve for the habitation of living creatures. But if these suns themselves are primary planets, we may see thousands at different periods with the naked eye, and millions with the help of telescopes; and at the same time, the analogical reasoning still remains in full force with regard to the planets which these suns may support. See Transactions of the Royal Society for the years 1794 and 6.—But to return to the Solar System.

The planets perform their revolutions about the sun, in elliptical curves, differing but little from circles, and of which the centre of the sun, or rather the common centre of gravity of the whole system, occupies one of the foci. Each of the planetary orbits is in a plane, which passes through the centre of the sun. The plane of the earth's orbit, that is, the path along which it travels, is denominated the plane of the ecliptic; it is that circle, which, to an inhabitant of the earth, the sun appears to describe in a year. By considering this plane as indefinitely extended on all sides, the planes of the orbits of the other planets may be supposed to be cut by it; and hence the positions of these, that is, the angles of their obliquity, are all referred to the ecliptic, or plane of the earth's orbit, as a scale by which they are measured. Thus the inclination of the orbit of Mercury to that of the earth is 7°, that is, one half of the orbit of Mercury rises above the orbit of the earth, and the other half falls below it. The following easy illustration of this principle has been given in some of our elementary treatises. Suppose a bowl, or other concave vessel nearly filled with water, the surface of which, when at rest, will trace a circular line round the inner surface of the bowl, which may represent the ecliptic, while the surface of the water is the plane of the ecliptic, and the bowl one half of the concave sky. If now a circular ring, hoop, &c. be immersed in the vessel of water, so that one half of it rises

above the surface, at an angle of 7°, the other half will be as much below, and the ring may represent the orbit of Mercury. Another ring rising above the surface of the water at an angle of about $3\frac{1}{2}°$ will represent the orbit of Venus; and so of the rest.

All the planets move in their orbits from west to east. The velocities with which they move, are not invariable, but the areas described by their radii vectores, that is, by lines supposed to be drawn from them to the centre of the Sun, are always equal in equal times, or proportional to the times of description. Therefore the motions of the planets are likewise so much the more rapid, as they are less remote from the sun; so that the magnitude of the orbit, and the slowness of the motion, concur in augmenting the durations of their sidereal revolutions.

Mercury and Venus are nearer the sun than the earth, therefore by us they are called *inferior* planets; those, which move in orbits beyond the orbit of the earth, are called superior planets. To the inhabitants of other planets, the terms inferior and superior, will be differently applied: to the earth there are, independently of the four small planetary bodies lately discovered, two inferior and four superior planets; but to an inhabitant of Jupiter, there are four inferior planets, and two superior.

Mercury is about 3,224 miles in diameter, and revolves round the sun in 87 days, at the distance of 37 millions of miles from that body. He is not often seen by the inhabitants of the earth, on account of his nearness to the sun, and to them he always appears on the same side of the heavens with the sun; of course he can be seen in the east, only in the morning a little before sun-rise; and in the west, in the evening a little after sun-set. When Mercury is viewed with a telescope of high magnifying powers, he exhibits nearly the same phases as the moon, being sometimes horned, and sometimes full, &c. It has never been completely ascertained whether he turns on his axis, though Schroeter suspected that he had discovered

his diurnal period to be equal to more than 24 of our days. The characteristics of this planet are thus described by the poet Mallet:

——————————Mercury, the first,
Near bordering on the day, with speedy wheel
Flies swiftest on, inflaming where he comes
With seven-fold splendour.

The seven-fold splendour refers to the quantity of light and heat which he enjoys, compared with the earth: "for light and heat are always diffused round the central body *inversely* as the squares of the mean distances of the planet from the sun;" thus Mars is about twice the distance from the sun that the earth is, and will enjoy only one fourth as much light and heat from the sun as we enjoy. So in calculating the quantities of light and heat enjoyed by Mercury, compared with what we enjoy, and knowing his distance from the sun to be 37,000,000, and the distance of the earth to be 95,000,000, we say, by the proposition above, calling the light or heat enjoyed by the earth as unity, $\overline{\frac{1}{95{,}000{,}000}}^{\,2} : \overline{\frac{1}{37{,}000{,}000}}^{\,2} :: 1$ to a fourth proportion, or omitting the cyphers, and by a common rule in fractions, it will be as $\overline{37}^{\,2} : \overline{95}^{\,2} : 1 : \overline{\tfrac{95}{37}}^{\,2} = \frac{9025}{1369} = 7$ nearly.

The diameter of Venus is not quite so large as that of the earth, being about 7,648 miles in length: she performs her revolution about the sun in 224 days, at the distance of 68 millions of miles from the sun; so that she will enjoy twice as much benefit from the sun with regard to light and heat, as we enjoy; for it will be as above $\overline{68}^{\,2} : \overline{95}^{\,2} :: 1 : \frac{9025}{4624} = 2$ nearly. With almost any telescope this beautiful planet exhibits all the same phases as those of the moon. Venus is an evening star, when she appears east of the sun; and a morning star, when she is west of him. Twice in the course of 120 years, Venus passes over the disc of the Sun; this phenomenon is denominated the transit of Venus; and, by

means of it, astronomers have been enabled to ascertain, with great accuracy, the distance of the earth from the Sun. Venus is thought to turn on her axis in about 23 hours and 20 minutes: she is said to have an atmosphere fifty miles in height. The inclination of the orbit of Venus to the plane of the ecliptic, is in an angle of nearly 4 degrees.

The earth, like the other planets, is spherical, but not an exact sphere. Its diameter is about 7,950 miles in length, but the diameter at the equator is 37 miles longer than that from pole to pole. It turns on its axis in about 24 hours, which causes the succession of day and night, every part of it being in that time, successively brought into, and continued in the light of the Sun. It has another motion in its orbit round the sun, which is performed in 365 days, 5 hours, 48 minutes and 49 seconds.

The diameter of the earth, in its course round the sun, is not perpendicular to its orbit, but inclined to it in an angle of $23\frac{1}{2}°$; it is owing to this that the days and nights are of different lengths, in different parts of the globe. The seasons of spring, summer, autumn, and winter depend, (1) on the length of the days and nights; and (2) upon the position of the earth with respect to the sun, that is, upon the perpendicularity with which the rays of the sun fall upon any particular part of the earth. We have observed that the motions of the planets in their orbits, are more rapid in proportion to their nearness to the sun: thus the velocity of Mercury is found to be at the rate of 105,000 miles in an hour; that of the earth, at the rate of 68,000 miles in an hour; and the velocity of Mars, is equal to 53,000 miles in an hour. The velocity of the same planet is different in different parts of its orbit: it moves faster when nearer the sun, and slower when farther from it.

Mars, the first of the superior planets, is distinguished from the rest by the redness of its colour, a circumstance that has been attributed to the density of its atmosphere. His figure, like that of the earth, is an oblate spheroid; and he travels

round the sun in about 687 days, at the mean distance of 144 millions of miles from that body. He has likewise a rotation on his axis in 24 hours, 39 minutes, a fact that has been discovered by means of an immensely large spot seen on his surface, when he is in that part of his orbit which is opposite to the sun and the earth. The orbit of Mars is inclined to the plane of the ecliptic in an angle of nearly two degrees.

The planet Ceres, if this and the three following be planets, when viewed through a good telescope, is of a ruddy colour, and appears to be of the size of a star of the eighth magnitude. It performs its revolution about the sun in 4 years, 7 months, and 10 days, at the mean distance of 260 millions of miles from that body. The magnitudes of this and the other bodies between Mars and Jupiter are not by any means clearly ascertained. Dr. Herschel makes the diameter of Ceres to be only 160 miles, whereas Schroeter makes it more than ten times as large, or 1,624 miles in length. The inclination of its orbit to the plane of the ecliptic is in an angle of more than 10 degrees.

Pallas is nearly of the same magnitude with Ceres, from which, and from all the other planets it is chiefly distinguished by the great inclination of its orbit to the plane of the ecliptic, making an angle of 34° nearly with it. Its mean distance from the sun is 266 millions of miles; the length of its year, which depends on its distance from the sun, is a little greater than that of Ceres.

Juno is of a reddish colour, and is less than either Ceres or Pallas, and is nearer to the sun than either of them: its mean distance from it being but two hundred and fifty-three millions of miles, and its annual revolution is equal to 4 years and 128 days of our time. The inclination of its orbit is 21 degrees. Schroeter has observed a very remarkable variation in the brilliancy of this planet, which he thinks is owing to some changes that are going on in its atmosphere, though it may, he says, arise from a diurnal rotation about its axis in 27 hours.

Vesta appears to be as large as a star of the fifth or sixth

magnitude, and has been frequently seen by the naked eye. Its light is more intense, pure and white, than any of the other three, and it is very similar in its appearance to the Georgium Sidus. It is nearer to the sun than the other three, and its year is about 3 years, 66 days, of our time. The inclination of its orbit is about 7°.

Jupiter is the largest of the planetary bodies, and next to Venus the brightest. When viewed through a good telescope, several belts or bands, darker in colour than the general surface, are observed across the disc parallel to his equator; which, as they are constantly varying, are supposed to be a series of clouds in his atmosphere. Spots have been occasionally discovered on the disc of this planet, from which his rotation on his axis has been estimated at 9 hours, 55 minutes, 37 seconds, of our time. Jupiter is 89,170 miles in diameter, which is eleven times longer than that of our earth; and as the apparent discs of planets increase according to the squares of their diameters, our earth will appear to an inhabitant of Jupiter 121 times less than that noble planet appears to us; for the disc of Jupiter is to that of the earth as $\overline{11}|^2 : \overline{1}|^2$ or 121 : 1. The bulks or magnitudes of the two bodies are to one another as the cubes of their diameters, that is, as $\overline{11}|^3 : \overline{1}|^3$ or as 1,331 : 1 : that is, Jupiter is more than 1,300 times larger than the earth. He performs his annual journey about the sun in something less than 12 of our years, at the distance of 493 millions of miles.

Jupiter, like the Earth and Mars, is an oblate spheroid; but owing to the velocity of his diurnal motion, his equatorial diameter is 6000 miles longer than his polar one. Jupiter, being five times farther distant from the sun than the earth, enjoys only a twenty-fifth part as much light and heat as we experience. He moves on his orbit most majestically, with his axis perpendicular to the plane of his orbit; of course his inhabitants will experience no change of seasons, nor difference in the length of their days and nights. These will be always nearly 5 hours each; at the equator of Jupiter there will be

perpetual summer, and at the poles an unceasing winter. The inclination of the orbit of Jupiter to that of the earth, or which is the same thing, to the plane of the ecliptic, is equal to $1\frac{1}{3}^{\circ}$ nearly.

The planet Saturn is more than 79,000 miles in diameter, and is distinguished, when observed by the naked eye, by its pale, and dead light, very unlike that of Jupiter and the other planets: from these he is also distinguished by a large luminous ring, which surrounds his body, which, as we have seen, was discovered by the celebrated Huygens; comparing Saturn with the other planets, he is thus described by the unfortunate Chatterton,

> But farther yet, the tardy Saturn lags,
> And *seven* attendant luminaries drags,
> Investing with a double ring his pace,
> He circles thro' immensity of space.

His distance from the sun being so great, 903 millions of miles, the motion of the planet in his orbit is proportionally slow; and his journey being so much longer likewise than that of the other planets, he takes almost 30 of our years to accomplish one of his: nevertheless, he travels at the rate of more than 20,000 miles an hour; and yet the poet, in speaking of this motion, calls it a *tardy, lagging motion.* The light and heat enjoyed by this planet from the sun, is only a ninetieth part of that which we enjoy, nevertheless the light is computed to be equal to that which 500 of our full moons would afford to us, and therefore it is only by comparison that our accomplished poetess, Mrs. Barbauld, speaks of his situation, as

> ———the dim verge, the suburbs of the system,
> Where cheerless Saturn, 'midst his wat'ry moons,
> Girt with a lucid zone, majestic sits.

When Saturn is examined with a good telescope, he appears to be of a spheroidal form, which arises from his rapid rotation on his axis, which is found to be performed in little more than 10 hours.

The surface of Saturn is diversified with dark spots and belts which are very changeable, but they are generally parallel with the ring. This ring, seen through a good telescope, is one of the most beautiful objects in nature; and it is found to consist of two concentric rings, detached from each other, and from the body of the planet, the innermost of which is nearly thrice as broad as the outermost. The dimensions of this magnificent zone, as determined by Dr. Herschel, are as follow:

	Miles.
Inside diameter of the interior ring	146,345
Outside	184,393
Inside . . . . exterior ring	190,248
Outside	204,883
Breadth of the interior ring	20,000
Breadth . . . exterior	7,200
Breadth of the dark space between the two rings	2,839

The inclination of the orbit of Saturn to that of the earth is about $2\frac{1}{2}°$.

The Georgium Sidus, called also the Herschel planet, and the Uranus, is, as far as has yet been discovered, the outermost body of the system. It is situated at about 1,818 millions of miles from the sun, and performs his journey in little more than 83 of our years. Its diameter is 35,112 miles in length, being about $4\frac{1}{2}$ times longer than that of the earth; of course the disc of our planet being 20 times less to the inhabitants of the Georgium Sidus, than he is to us, it must be wholly invisible to them without the aid of very powerful glasses. When seen with the naked eye, which it may sometimes, it appears as a fixed star of the sixth magnitude, with a bluish white light, and of a brilliancy between that of Venus and the Moon.

Some of the planets, as the Earth, Jupiter, Saturn, and the Georgium Sidus have moons or satellites, which revolve about them, as they revolve about the Sun. Thus the earth has one,

which we denominate our moon; Jupiter has four; Saturn seven, and the Georgium Sidus six. With respect to these satellites, or as they are sometimes called, secondary planets, there is this remarkable circumstance attending the moon, the four satellites of Jupiter, and one of Saturn, that they are found to turn about their axes in the same time as they respectively revolve about their primaries. And although it has not yet been ascertained from observation, whether the same be true of the other satellites of Saturn, and those of the Georgian planet; yet astronomers conclude, from the uniformity which pervades the system, that the same is true of all the secondaries.

Next to the sun, the moon is the most conspicuous of the heavenly bodies, and that with which the inhabitants of the terraqueous globe are most interested. The changes which it undergoes, are more striking and more frequent than those of the sun, and its apparent motions much more rapid: hence they were attended to, even before those of the sun were known, or even regarded; a fact which explains the reason, why the first inhabitants of the earth reckoned their time by the moon's motions, and of course followed the lunar, rather than the solar year.

The moon has a motion in her orbit, from west to east, which is ascertained from observation; for if we attend to her any evening at a particular hour, when she is situated in the vicinity of a fixed star, we shall find on the next evening at the same time, that she is about 13° east of that star; and her distance continually increases, till at length, after a certain number of days, she returns again to the same star, having performed a complete revolution in the heavens.

It is ascertained that the moon makes a complete revolution in the heavens in 27 days, 7 hours, 43 minutes, 5 seconds, which compass of time is called a periodical month; but her period from one conjunction to another, that is, from new moon to new moon, or from full moon to full moon, takes up 29 days, 12 hours, 44 minutes, 3 seconds, which space is called a synodical month or a lunation. For while the moon,

in its proper orbit, finishes her course, the earth, together with the moon, and its orbit, are advancing in their journey round the sun, and have proceeded almost a whole sign in the ecliptic towards the east; so that the point of the moon's orbit, which in the former position was placed in a right line joining the centres of the earth and sun, is more westerly than the sun; therefore, when the moon has again arrived at that point, it will not yet be seen in conjunction with the sun.

The orbit of the moon is not in the same plane with the orbit of the earth, that is, in the ecliptic; but, like the orbits of the planets, is inclined to it in an angle of about $5\frac{1}{4}°$. These two imaginary planes are therefore supposed to cut each other in two points, which points are called the nodes; and it is only when the moon is in one of these nodes, that the moon is seen in the ecliptic. At other times it is either north or south of it. The right line, which passes through the centre of the earth, and joins the two nodes, is called the *line of the nodes*. The nodes are not constantly in the same place, that is, the moon's orbit does not constantly intersect the ecliptic in the same points; so that the line of the nodes continually moves from the east towards the west, contrary to the order of the signs of the ecliptic; therefore, if the moon be observed to cross the ecliptic at any particular place, at the next lunation it will be found to cross the ecliptic at another place, which is a little westward of the former. By this continual shifting from the east towards the west, the line of the nodes performs the whole revolution in the compass of about 18 years, 228 days, and 5 hours; after which time, the nodes return to the same points of the ecliptic.

The farther the moon is from the nodes, the farther distant she is from the ecliptic; the points of her orbit, which are farthest from the ecliptic, and which are called the *limits*, must evidently be equidistant from the nodes. This distance, which never exceeds $5° \ 18' \ 6''$, is called the moon's latitude; for generally, the latitude of a celestial object is its angular distance from the ecliptic, and is measured by an arc of a

circle drawn through the moon, and perpendicular to the ecliptic.

The moon's motion in her orbit, the inclination of that orbit to the ecliptic, and the retrogradation of the nodes, point out the causes of eclipses of the moon and sun, and the reasons why they are sometimes partial and sometimes total;—why they do not take place at every new and full moon; and, finally, why they return very nearly in the same order after about every 19 years. Into these various subjects, the limits of our work do not permit us to enter much at large; nor can we attempt to explain the irregularities of the moon's motions, which are very considerable, and which for a long time baffled the skill of the ablest astronomers. The only equable motion belonging to the moon, is its revolution on its axis; which, as we have observed, is performed exactly in the same time in which she performs her revolution in her orbit round the earth; hence she always presents the same half of her surface to us, while the other half is never seen by the inhabitants of the earth: hence it also follows, that in the compass of one year, though we have $365\frac{1}{4}$ days, the inhabitants of the moon have only between 12 and 13 days, each of their days being equal to about $29\frac{1}{2}$ of our days. The inclination of the moon's axis to the plane of the ecliptic, is in an angle of 88° 17′ nearly.

The mean distance of the moon from the earth, is 240,000 miles, and its diameter is equal to about 2,200 miles in length; so that the bulk of the earth, being to that of the moon as the cubes of their diameters, the former will be about 49 times larger than the latter.

The different phases of the moon, that is, those periodical changes to which its light and apparent figure are subject, and the eclipses of that body and of the sun occasioned by it, constitute, and ever have constituted, some of the most striking phenomena of the heavens: we shall therefore give a very brief elucidation of them, such as we trust will satisfy general readers; the scientific we shall direct to different sources of information.

When the moon is due south about midnight, her disc is an entire circle, that is, it is full moon. On the next night she comes later to the meridian by about 48 minutes; this, though varied at different seasons, is the average, and the western part of her disc is no longer bounded by a circular, but by an elliptic line, and this line every following night is seen to encroach more and more on the luminous part, till, on the seventh night, it is nearly a straight line, and the disc a semicircle, the moon is then said to be in its quadrature. The diminution continues, and the disc becomes more and more concave to the west, till about the end of another seven days, when it disappears altogether. After three or four days the moon again appears like a fine crescent, to the eastward of the sun, with its concavity turned toward the east; when it goes on increasing on that side, till it becomes again a perfectly circular disc, which is about 29½ days from the time when she wore that appearance before.

The moon, during the changes which we have just described, appears to advance among the fixed stars at the rate of 13° 10′½, on the average, in 24 hours; and, for the reason already assigned, comes later to the meridian by about 48 minutes every day. The phases may be all explained on the supposition that the moon is an opaque spherical body, which moves in a circular or elliptic orbit round the earth, while it receives its light from the sun.

The moon, when *full*, is opposite to the sun, that is, the earth is situated between the sun and moon; when she disappears, that is, just before the new moon makes her appearance, she is in conjunction with the sun, in other words, she is situated between the sun and the earth; of course her illuminated side is towards the sun, and her dark side to the earth.

The cause of the phases of the moon is thus explained. Let S represent the sun, fig. 2, T the earth, Q L a portion of the earth's orbit, which it describes in its annual course round the sun; A, B, C, &c. represent the orbit of the moon,

in which she turns round the earth, in the space of $29\frac{1}{2}$ days from the west to the east. Join the centres of the sun and moon with the right line S L, and through the centre of the moon, suppose a plane *x z*, perpendicular to S L, to pass, the section of that plane with the surface of the moon, will produce the circle which bounds light and darkness on her surface, and separates the enlightened face from the dark side. In this case the whole enlightened side of the moon is turned from the earth T, and she is not visible. When the moon is in the position F, let the centres of the sun and moon be joined by the right line S *r*, which is perpendicular to a plane *m n* passing through the centre of the moon, that plane will make on the surface of the moon, the circle which distinguishes the visible hemisphere, or that which is towards us at T, from the invisible which is turned from us; now it is manifest that only the small part of the enlightened side of the moon *m o*, is turned to the earth, and it will appear horned, as at *f*. When the moon has advanced to G, a larger part of her illuminated surface will be seen from the earth, and she will appear as at *g*. At A in the point of the orbit opposite to the Sun, the circle bounding light and darkness, and the circle of vision will coincide, and then all the illuminated face of the moon will be turned towards the earth, and will be visible to its inhabitants, as it appears at *a*. Then the moon is said to be full: she shines the whole night; and is said to be in opposition: for the sun and moon with respect to the earth, are seen in opposite parts of the heavens, the one rising when the other sets. When the moon comes to B, the whole illuminated disc *x y z*, is not turned towards the earth, and the visible illumination will be deficient from a circle, and the moon will have a gibbous form, such as is marked in *b*.

The opacity of the moon is proved not only from her phases, but from the occultation of stars by the dark, or invisible part of her orb.

Of Eclipses.—When any one of the heavenly bodies is obscured, or darkened by the shadow of another falling upon it, or by the interposition of any body, it is said to be eclipsed.

The eclipses of the sun and moon are the most striking of any. They were formerly considered as ominous, and have often excited the dread and apprehension of the vulgar; but the improvement of science has shewn, that they depend upon regular and invariable causes, and may be calculated and foretold with the greatest certainty.

As the earth is an opaque body, enlightened only by the sun, it will cast a shadow towards that side which is farthest from the sun. If the sun and earth were of the same size, this shadow would be cylindrical, and would extend to an infinite distance; but as the sun is much larger than the earth, the shadow of the latter must be conical, and end in a point (see Fig. 3, Plate V.) On the sides of this conical shadow, there is a diverging shadow, the density of which decreases, in proportion as it recedes from the sides of the former conical shadow: this is called the penumbra. As the moon revolves round the earth, sufficiently near to pass through the shadow of the earth, an eclipse must always take place when the earth, the sun, and the moon are all in one straight line. An eclipse of the moon can never happen but at the time of full moon; but on account of the inclination of the moon's orbit to that of the earth, an eclipse cannot take place every full moon. When the moon passes entirely through the earth's shadow, the eclipse is total, but when only a part of it passes through the shadow, the eclipse is partial. The quantity of the moon's disc which is eclipsed (and the same thing is to be understood of that of the sun, in a solar eclipse) is expressed by twelve parts called digits: that is, the disc is supposed to be divided by 12 parallel lines; then if half the disc is eclipsed, the quantity of the eclipse is said to be six digits. When the diameter of the shadow through which the moon must pass, is greater than the diameter of the moon, the quantity of the eclipse is said to be more than 12 digits; thus if the diameter of the moon is to that of the shadow as four to five, then the eclipse is said to be of 15 digits.

The eclipses of the sun are owing to a different cause from those of the moon. They are occasioned by the moon's

coming directly between us and the sun, and therefore obstructing our view of it. When the moon happens to be in conjunction with the sun, or between the sun and the earth, viz. at the time of the new moon, the shadow of the moon falls upon the surface of the earth; hence, properly speaking, such eclipses should be called eclipses of the earth. But the whole disc of the earth cannot be involved in the shadow of the moon, because the moon is much smaller than the earth, and the shadow of the moon is conical. Thus, in Fig. 4, Plate V. the rays of the sun being intercepted by the moon L, the conical shadow CDG, is formed; which, falling upon the surface of the earth, entirely deprives the portion of it upon which it falls, of the sun's light, and, of course, the inhabitants of that part of the earth will have a total eclipse of the sun. Beyond the dense conical shadow CDG, there is a diverging half shadow, or penumbra, CDEF, which is occasioned by the moon's intercepting only a part of the sun's rays from those places which fall within this penumbral cone, and are out of the dense shadow. Thus from the part of the earth Z, the portion YYB of the sun only can be seen; consequently the inhabitants of that part will have a partial eclipse.

As the moon is not always at the same distance from the earth, it sometimes happens that the conical dense shadow does not reach the earth, as in Fig. 5. and only the penumbral shadow falls upon it; the eclipse, consequently, is partial to every part of the earth. Those who are at the centre of the penumbra will lose sight of the centre of the sun, by the interposition of the moon's body, which, subtending a smaller angle than the sun, will not entirely cover its surface: so that there will be a ring of light. The eclipse is then said to be annular.

Seven is the greatest number of eclipses that can happen in a year, and two the least. If there are seven, five must be of the sun and two of the moon. If there are only two, they must be both of the sun: for in every year there are at least two eclipses of the sun. There can never be more than

three eclipses of the moon in a year, and in some years there are none.

Though the number of solar eclipses is greater than of the lunar, in the ratio of 3 to 2, yet more lunar than solar eclipses are visible in any particular place, because a lunar eclipse is visible to an entire hemisphere, and a solar one only to a small part of it.

It is the lot of few persons to witness central eclipses, so that they may be considered as rare phenomena; nevertheless there are 28 such eclipses in each cycle of eighteen years, but the space over which every one of them appears to be central, is but a very confined tract. A beautiful phenomenon of this kind occurred to the inhabitants of London, in April, 1715, which is described by Dr. Halley. The darkness for a short time was so entire, that the stars became visible. Though the disc of the sun was wholly covered by the moon, a luminous ring of a faint pearly light surrounded the body of the moon, the breadth of which was about the tenth of the moon's diameter. In no part of this country did the obscuration last more than 3 minutes 57 seconds.

The satellites, or moons, of Jupiter, Saturn, and the Georgium Sidus, are often eclipsed by the planets to which they belong. The eclipses of Jupiter's moons are of much importance in astronomy and navigation; and observed with great attention, as being extremely useful in ascertaining the longitude.

When any of the planetary bodies disappear by another, or by the moon coming before it, it is called an occultation. The occultations of the fixed stars by the moon, are likewise of great use in determining the longitudes of places.

Of the Tides.—The ebbing and flowing of the sea were first shewn by Kepler, to be owing to the moon's attraction: and Newton demonstrated it upon the principles of gravitation. The attraction of the moon cannot alter the shape of the solid parts of the globe, but it has a considerable effect upon the fluid part, which it causes to assume a spheroidal figure, the longest axis being in the direction of the moon.

It is, therefore, the highest tide at that place perpendicularly under the moon, or where the moon crosses the meridian.

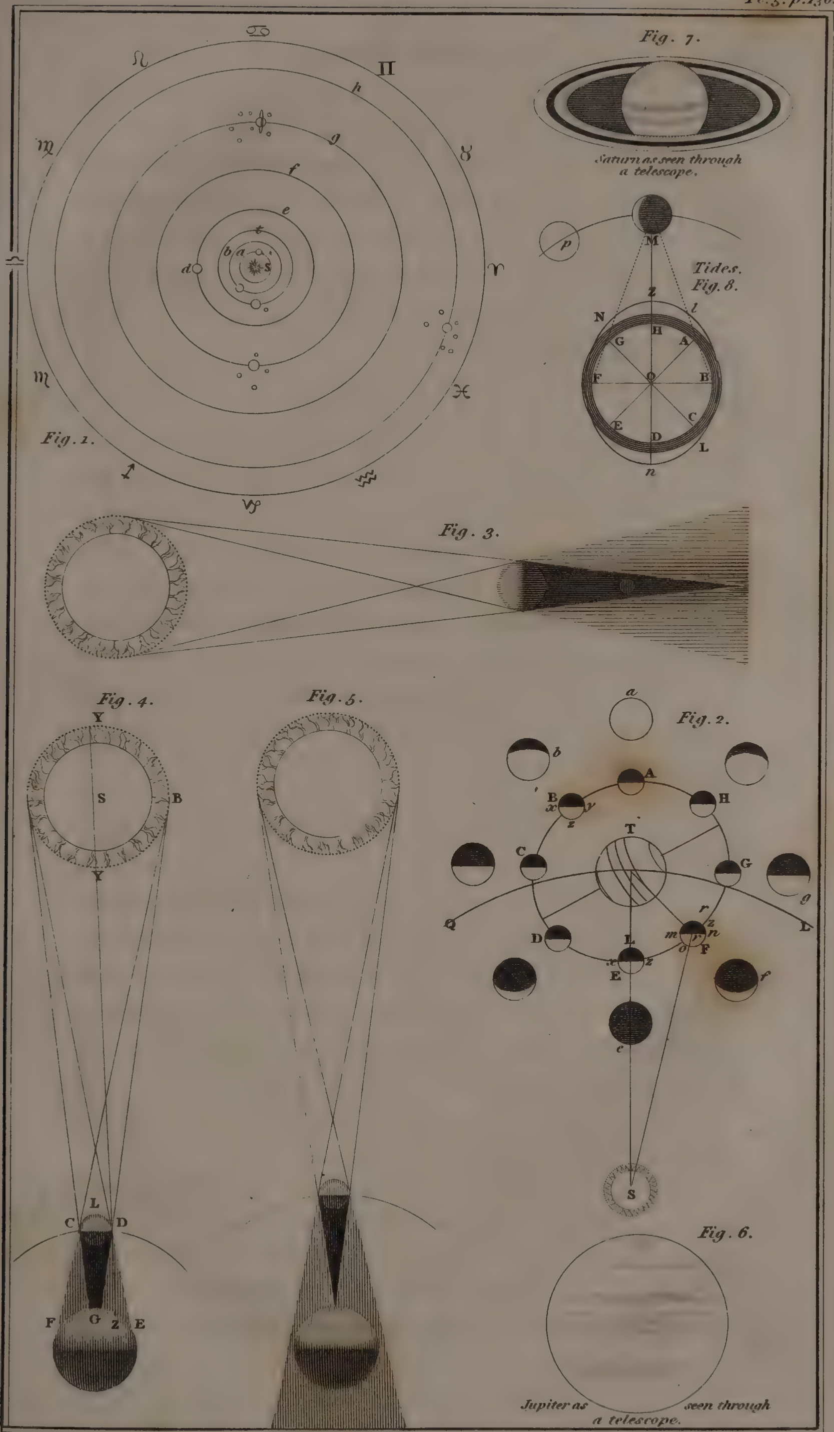
The sun also has some action on the waters, though its attraction, on account of the distance, is not so strong as that of the moon. When the action of the sun and moon conspire together, the tide rises higher, and produces what are called spring tides. On the contrary, when they counteract each other, they produce neap tides.

Of the various treatises on Astronomy, which may be mentioned as among the most popular, are the second volume of the "Scientific Dialogues," and Bonnycastle's Introduction to Astronomy: of a higher order may be named the treatises by Mr. Ferguson, and Dr. Olinthus Gregory. "The Astronomical Lectures" of Dr. John Keill, and the "Elements of Physical and Geometrical Astronomy," by David Gregory. M. D. though not modern works, and of course deficient in respect to the discoveries of the last forty years, are nevertheless very good as far as they go, and may frequently be purchased for a trifle. Dr. Vince's Complete System of Astronomy, in three volumes, 4to., is the most extensive and useful body of science which has yet been published in this country: on the continent, Lalande's System of Astronomy is deservedly in the highest estimation.

The great work on Astronomy, so regarded by the philosophers and mathematicians of all countries, is that entitled "Philosophiæ Naturalis Principia Mathematica, auctore Isaaco Newtono." This, however, can be read only by mathematicians of the very highest order. As introductory to it, we have "A View of Sir Isaac Newton's Philosophy by Henry Pemberton," 4to; and, which is by much the more extensively useful work.

"An Account of Sir Isaac Newton's Philosophical Discoveries, by Colin Maclaurin." Also

"A Demonstration of some of the principal Sections of Sir Isaac Newton's Principles of Natural Philosophy; in which his peculiar method of treating that useful subject is explain-



Lowry Sc.

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ed, and applied to some of the chief phenomena of the system of the world, by John Clark, D. D." To these may be added an unfinished work by Mr. Thorp, who, in 1777, published the first book of the *Principia*, with a very good commentary. The most elaborate commentary on Sir Isaac Newton's Principia, is generally known in this country by the title of the Jesuit's edition of the Principia: it is in the Latin language, and entitled, "Philosophiæ Naturalis Principia Mathematica, auctore Isaaco Newtono: perpetuis Commentariis illustrata communi Studio, P. P. Thomæ Le Seur et Francisci Jacquier, &c. &c." This work is very rare in England; it is sometimes bound in three vols. 4to. but the copy in our possession is in four thin vols.

The late excellent mathematician, Dr. John Jebb, published "Excerpta" from the Principia, in one vol. 4to., chiefly intended for the students of the University at Cambridge. This also is scarce, but we believe not much read beyond the University for which it was drawn up.

The best edition of Sir Isaac Newton's works is that by the late Bishop of Rochester, in five very large 4to. volumes, entitled "Isaaci Newtoni Opera quæ extant omnia, Commentariis illustrabat, &c. Londini, 1779." A very excellent treatise on astronomy is contained in the first volume of "Elements of Mechanical Philosophy, by the late Professor Robinson of Edinburgh. L'Exposition du Systeme du Monde par P. S. Laplace," in 2 vols. 8vo. is a very valuable work on astronomy in its present form: and to those who can attempt the higher branches of this science we would recommend the study of "Mecanique Celeste," by the same author, a profound work, which exhibits the perfection of astronomy.

In Dr. Vince's work already referred to, is an interesting history of the rise and progress of the science of Astronomy. The following works are more avowedly historical performances, and may be recommended to readers; who should, however, be reminded, that neither of them contains the important discoveries of modern times. They may frequently

be purchased for a trifle, and will be an acquisition to the lovers of science.

"Astronomy, in five books, by Roger Long, D. D." 2 vols. 4to. It rarely sells higher than from about ten to twelve shillings. It is often bound in three volumes.

"The History of Astronomy, with its application to Geography, History and Chronology, &c. by George Costard," 4to. 1767. In this is included an introduction to the use of the globes, but not systematically arranged. This work, like the last, may frequently be purchased at a very easy rate, and is deserving a place in the student's library.

In Practical Astronomy, we may mention as exceedingly useful to the young observer:

"An Introduction to Practical Astronomy; or the Use of the Quadrant and Equatorial, by George Adams."

"A Treatise on Practical Astronomy, by Dr. Vince." This is a thin quarto; it contains a description of the several instruments in Practical Astronomy, and rules for computing and deducing the conclusions for which the observations are made.

For those young persons who would be Conversant with the constellations, and principal fixed stars, and who have not access to a good celestial globe, we may recommend a little work, entitled

"Astrarium, or Principal Views of the Fixed Stars and Constellations, represented in twelve plates, one for each month in the year."

Having gone through the several departments of Natural Philosophy, and mentioned a few of the authors in which each branch of the science may be studied with advantage, by persons of different capacities and attainments in knowledge, it now remains to say a few words upon the subject more generally.

To books of science should, if possible, be added a course of experiments; it is an unfortunate circumstance, that the apparatus for demonstrating the facts in natural and experimental philosophy is necessarily very expensive; attempts have

been made to invent a collection of instruments that should come within the reach of persons in moderate circumstances, but without success. In schools, not exclusively devoted to classical literature, it is usual during each year, for the preceptor to go through a course of experimental philosophy, which cannot be without its use: it excites the curiosity of young people, and may induce them hereafter to pursue science for its own sake, and furnish them with materials for thinking, and for spending their time in a rational and useful manner.

It has been doubted whether experimental philosophy should be taught in the schools. If the genius of all children took the same direction, there would be no need of variety in their education; but as this is not the case, as their talents are as various as their dispositions, there seems no reason why different objects of pursuit should not be presented to them, thus leaving them, in some measure, to strike out for themselves their favourite studies. It has been asserted that the facts in natural philosophy could not be taught so readily as definitions in grammar; this has, however been shewn to be erroneous; a work entitled "A Familiar Introduction to the Arts and Sciences," has been drawn up expressly with that view, divided into sections, containing about ten or twelve facts to be committed to memory; to which are added, where the subject requires it, illustrations, with references to plates, and questions adapted to the use of masters. These questions are placed in the exact order of the facts, but in examination they may be varied at the pleasure of the teacher. By the same author there are two other works adapted to young people, still farther advanced in the path of knowledge. These are "Scientific Dialogues," in six small volumes, which in the course of fourteen or fifteen years, have been very frequently reprinted, and have obtained a decided share of the public approbation: and "Letters on Natural Philosophy," in one vol. 12mo.

Of the same kind as the latter, but not embracing so many subjects, are "Lectures on Natural and Experimental Philosophy," in 2 vols. 12mo. by Dr. George Gregory.

"Elements of Science and Art, by Thomas Webster," in two volumes, 8vo. is an excellent introduction to the several sciences on which they treat, including chemistry, and the application of mechanics, chemistry, &c. to a variety of elegant and useful arts.

In the second edition of "Enfield's Institutes of Natural Philosophy," introductions to chemistry, electricity, and magnetism, are added to the other departments of experimental philosophy, and the whole brought down to the time of the publication, in 1799: there is an advantage attaching to this, and to Martin's "Philosophia Britannica," which does not belong to those before mentioned, viz. the application of the elementary principles of mathematics to many of the cases that admit of it. The same may be said of Mr. Cavallo's "Elements of Natural and Experimental Philosophy," in 4 vols. 8vo. which is a book of real merit, but the style is not always simple and clear. Nicholson's "Introduction to Natural Philosophy," in two volumes, 8vo. may be recommended: as may Adams's Lectures in five volumes. The later editions by Jones, are much superior to the original one by Mr. Adams.

"An Elementary Treatise on Natural Philosophy by M. R. J. Hauy," translated into the English by Dr. Olinthus Gregory, is not so well known as its merits deserve. It treats principally on the forces of bodies, Hydrostatics, Pneumatics, Electricity, Magnetism and Optics. "Elements of Natural Philosophy," by Musschenbroek, translated by Colson, is a good treatise on the mechanical powers.

"Mathematical Elements of Natural Philosophy, &c. by James s'Gravesande, LL. D." translated from the Latin, by Dr. Desaguliers: and

"A Course of Experimental Philosophy, by Dr. Desaguliers," are very elaborate and excellent works, and were extremely popular during the greater part of the last century; they are still deserving a place in the libraries of the learned.

"A Course of Lectures on Natural Philosophy, and the Mechanical Arts, by Thomas Young, M. D." 2 vols. 4to. These lectures were originally delivered in the theatre of the

Royal Institution, in which the author, instead of compiling from the elementary works then existing, resorted to the original authors, and endeavoured to digest into one system every thing relating to the principles of the mechanical sciences, that could tend to the improvement of those arts, which are subservient to the conveniencies of life. Upon this plan the first volume is drawn up, and it includes all the branches of natural and experimental philosophy, with a very brief outline of natural history. The volume is divided into sixty lectures; twenty on Mechanics and the Mechanical Arts: twenty on Hydrodynamics, and the same number on Physics. The plates, which are numerous, are referred to in the body of the work, but explained at the end of the volume: in many cases the explanations are much too brief for learners. Dr. Young's second volume contains: 1. The Mathematical Elements of Natural Philosophy. 2. A Systematic Catalogue of Works relating to Natural Philosophy and the Mechanical Arts, with references to particular passages, abstracts, and remarks. 3. Miscellaneous papers on subjects connected with the topics discussed in the volumes. Dr. Young's work is very valuable as a book of reference, but it will be found to be better adapted to the library of a philosopher and man of general reading, than to the uninitiated student.

In addition to the foregoing works, we may notice another class of authors, viz. those who give a syllabus, or outline, to be filled up by a person's own reading and researches: such is "A Plan of a Course of Lectures on the Principles of Natural Philosophy, by the Rev. Dr. Vince." This work was intended for the students of Cambridge, and was well adapted to recal to the mind all the facts and demonstrations detailed and exhibited in the public lectures.

On a larger and more useful scale, is a work very lately published by Mr. Playfair, entitled, "Outlines of Natural Philosophy, being heads of lectures delivered in the University of Edinburgh." In these the author has given references to those works in which his subjects are treated of at large.

CHAP. VI.

CHEMISTRY.

Importance of Chemistry to the Arts and Manufactures—Divisions of Chemistry. Simple Substances. Light—Caloric—Oxygen—Sulphur—Phosphorus—Carbon—-Hydrogen—Metals—Earths—Alkalies—Acids.

THE object of Chemistry is to ascertain the ingredients of which bodies are composed, to examine the compounds formed by the combination of these ingredients, and to investigate the nature of the power which occasions these combinations. As an art, Chemistry is connected with the most important branches of manufactures, and in proportion to the progress made in chemistry, a higher degree of perfection may be looked for, in the several processes which are necessary to the conveniencies and elegancies of life. The glass and porcelain manufacturers, the workers in metals, the dyer and bleacher, the tanner and soap-boiler, with many others, depend on chemistry for improvement in their several arts. As a science, it is connected with almost all the phenomena of nature; with the causes of rain, snow, and earthquakes:—with the production, growth, and maturity of the vegetable world:—and with the functions of animals; exhibiting the manner by which the food, taken into the stomach, is

rendered subservient to the nourishment of the body and the support of life.

The science, as such, naturally divides itself into three parts. 1. A description of the component parts of bodies, which are denominated simple substances. 2. A description of bodies compounded of these simple substances; and 3. An account of the nature of the *affinity*, or that power which occasions these combinations.

Of simple substances, which in a chemical sense, signify those bodies that have not hitherto been decompounded. Many substances, which were thought to be simple by the ancients, are now ascertained to be compounds; such is the atmospheric air, and such is water. And many that were supposed to be simple, ten or fifteen years ago, have been decomposed by Sir Humphry Davy, and the component parts clearly exhibited to the senses; such are the alkalies and earths. Till very lately, simple bodies have been arranged in the following manner:

1. Imponderable substances, as	Light. Caloric. Oxygen.	
2. Ponderable and combustible substances, as	Sulphur. Phosphorus. Carbon. Hydrogen.	
3. Metallic substances, which are divided into the	*Malleable*, as	Gold, Lead, Iron, &c.
	Brittle, and easily fused, as	Bismuth, Antimony, &c.
	Brittle, and fused with difficuly, as	Cobalt, Manganese, &c.
4. The Earths.		
5. The Alkalies.		

Although some of these substances, particularly the Alkalies, are known to be compound substances, yet we shall follow this arrangement, as adapted to give the reader an insight into modern chemistry, and because the subject is treated of in a similar manner in many of our best elementary treatises.

Light. Of the mechanical properties of Light we have spoken in the article *Optics*; we have, therefore, here only to describe the chemical effects produced by light, on vegetable,

animal, and other substances. Vegetables are indebted to light for their colour; since if they grow in darkness, or their leaves are tied up, so as to exclude the light, they become white; on this depends the theory of blanching lettuces, kale, endive, &c. Light contributes also to the taste and the odour of fruits and seeds. The action of the sun's rays on vegetables, causes them to give out abundance of pure air, but at night they emit a gas of the most noxious quality.

Animals, in general, droop, become unhealthy, and die, when deprived for a considerable time of light. Grubs and other insects that live in the earth, are of a whitish colour. The parts of birds, and even fishes, exposed to the light, are coloured; but those parts to which the light never, or but rarely approaches, are uniformly without colour. Many of the metallic oxydes become of a deeper colour when exposed any length of time to the rays of the sun: some of them are reduced, and the oxygen escapes, on being exposed to the light of the sun.

Light is capable of entering into, and remaining in bodies, and of being afterwards extricated without alteration. Thus, calcined oyster-shells prepared with sulphur by heat, and kept for use, in a well stopped phial, will, when exposed a few seconds to the light, become sufficiently luminous to enable a person in a dark room to distinguish the time on his watch. After a short period it ceases to shine, but it recovers this property on being again exposed to the light. Light, therefore, is not only acted upon by other bodies, but is capable of uniting with them, and afterwards leaving them without change. Substances of the kind we have been describing, of which there are many, are denominated phosphori.

Light combines with bodies, and constitutes one of their component parts. Different kinds of meat and fish, beginning to putrefy, become luminous in the dark, and of course give out the light which was combined with their substances.

Exp. Put half an ounce of whiting, or herring, or mackerel in a phial, with two ounces of pure water, holding in

solution half a dram of common salt, place the phial in a dark place, and in two or three days a ring of light will appear on the surface of the liquid, and by agitation the whole liquid becomes luminous, and continues in that state for some time. A moderate heat increases the luminous quality, but a boiling heat extinguishes it altogether. This light produces no sensible effect on the thermometer; hence it is inferred that light constitutes a component part of these substances, and that it is the first of the constituent parts which makes its escape when the substance containing it is beginning to be decomposed.

Almost all bodies have the property of absorbing light, though only a few of them emit it again. They do not, however, absorb all rays indiscriminately: some absorb one coloured ray, others another, while they reflect the rest; which is the cause of the different colours of bodies. What we call a green body reflects the green rays, and absorbs the others: red bodies reflect the red rays, and absorb the others; and so of the rest. Hence it is assumed, that the different colours of bodies depend upon the affinity of each for some particular rays, and its want of affinity for the others.

The different sources from which light is emitted in a visible form, are: 1. The *sun* and fixed stars. 2. *Combustion,* which is the act of combination of the combustible with oxygen; of course the light emitted must have existed previously, combined with the combustible or the oxygen. 3. *Heat,* when a body becomes luminous by being heated in the fire, it is said to be red hot; and it is found, that all bodies which are capable of enduring the requisite degree of heat, without decomposition or volatilization, begin to emit light at the same temperature. Thus iron is just visible in the dark, when heated to 635° of Fahrenheit; it shines strongly in the dark, at 752°; it is luminous in the twilight, just after sunset, when heated to 884°; and it shines even in broad day-light, if its temperature is about 1000°. 4. The last source of light is *percussion;* thus, when flint and steel are smartly struck against each

other, light is produced, which is capable of inflaming tinder, gunpowder, &c. The spark is a small particle of the iron, which is driven off, and takes fire during its passage through the air. This is an instance of combustion. But light is emitted when two quartz stones are smartly struck against each other, though the substances are clearly incombustible.

Caloric. What we call heat, is a sensation produced by a substance denominated *caloric;* which, though never existing alone, penetrates all bodies;—diminishes the attraction of their several parts; and uniformly expands their dimensions. By means of caloric, solid metals are fused—liquids rarefied; and, in short, all substances in nature may be converted into elastic, compressible, and aeriform fluids. Hence it is asserted by Lavoisier, that all bodies, of whatever kind, may subsist in three forms, viz. the solid, the fluid, and the äeriform. Liquids are combinations of solids with a larger portion of caloric than they usually contain: such are fused metals, such is water. In the reduction of solids to a fluid state, caloric is absorbed; on the contrary, liquids in becoming solid, give out caloric; the melted metals in becoming solid, and water in the act of freezing, give out a portion of their caloric to the surrounding bodies.

Caloric exists in all bodies in two states: in one it is called *combined,* in the other *sensible.* The former is retained in bodies by the force of affinity or attraction, and is in fact, part of their substance; whereas sensible caloric may be measured by the thermometer.

Caloric in combination may be disengaged by various means; as in the case of coal, wood, &c. which, when inflamed, give out heat. In mixing sulphuric acid with water, a deal of heat is given out to surrounding bodies. Caloric, under different circumstances, enters into combination, thus, mixing ice with common salt or nitre, the sensation of cold is produced, because a quantity of the sensible heat in one or both substances is absorbed.

Uncombined caloric has a tendency to any equilibrium; thus any number of different bodies, at various degrees of

temperature, if placed under similar circumstances of exposure, acquires a common temperature. If there be placed in an atmosphere of 55°, iron filings made red hot, boiling water, and other substances of different degrees of temperature, they will all soon become of the same temperature, as may be seen by the thermometer.

All bodies are in a greater or less degree conductors of caloric. Metals and liquids are good conductors of heat, but silk, cotton, wool, wood, &c., are bad conductors of it. A short poker, or other piece of iron, put into the fire at one end, will very soon become hot at the other: this will not be the case with a piece of cane or wood of the same length, and under precisely the same circumstances. A person with a silken purse containing metal coin, may stand so near the fire, as to make the metal almost too hot to touch, though the temperature of the purse will apparently be scarcely altered.

Solid bodies transmit caloric in all directions. If iron, or other metallic substances, branch out in bars from a centre, and that centre be heated, every bar will be equally heated. Some bodies conduct caloric more rapidly than others. Coat rods of iron and glass of equal length with wax, at one end of each only, and apply the same degree of heat to the other ends, the wax will become soft much sooner at the end of the iron, than on that of the glass, which shews that iron conducts heat more quickly than glass. Different metals also possess very different powers of conducting caloric, as may be ascertained by experiment.

Caloric expands all bodies. In liquids this fact is shewn by the expansion and contraction of the mercury or spirit in the thermometer, or by immersing in hot water a glass bulb with a long neck, and filled up to a certain point with any coloured fluid. The degree of expansion produced in different liquids varies considerably: water is more expansible than mercury, and alcohol than water. The expansion of aeriform bodies is shewn by bringing near the fire a small quantity of air, tied closely up in a bladder. The expansion of solids is exhibited

by the pyrometer, which, in principle, is a bar of iron made to fit exactly, when cold, between two points, and the diameter such as barely to allow it to pass through an iron ring; when heated, it will become sensibly longer, and it will be then found incapable of passing through the ring. The degree of expansion is not the same for all solids, and differs materially in substances of the same class; thus copper is more expansible than iron, and iron than platinum. The construction of the thermometer is founded on the principle of expansion.

Oxygen, like caloric, has never been obtained alone, and independently of other substances with which it is combined. When it is combined with caloric, it is called oxygen-gas; though in many elementary books, oxygen and oxygen-gas are used as synonymous terms. Oxygen is one of the most important agents in nature: there is scarcely a single process, either natural or artificial, in which oxygen has not a share. The great sources whence oxygen-gas is derived, are water and air: in the former it is combined with about the third of its weight of hydrogen; in the latter it is united with azotic gas, or, as it is called, nitrogen, and forms about $\frac{1}{5}$ of the atmosphere, the other $\frac{4}{5}$ths are of nitrogen. It is, however, obtained from many other substances, as from, or by means of vegetables, the mineral acids, and metallic oxydes. Oxygen is necessary to support combustion, and during the process, it combines with the combustible body. Many of the substances, into the combination of which oxygen enters, are important agents in chemistry; such are mineral acids, the activity of which depends, no doubt, upon the oxygen which they contain. All metals combine with oxygen, and in that state they are called metallic oxydes. Phosphorus, sulphur, and other substances, unite with oxygen, and form oxydes, and acids of greater or less strength, according to the proportion of oxygen they contain: thus

Phosphorus, with a small portion of oxygen, forms an oxyde of phosphorus.
———————— larger ———————— phosphorous acid.
———————— the largest ———————— phosphoric acid.

In the same way Nitr*ous* and Nitr*ic* acids: Sulphur*ous* and Sulphur*ic* acids are formed. The combination of oxygen with other bodies, is called their oxydation or oxygenation. With respect to acids, the terminations *ous* and *ic*, always denote the lower and higher degrees of oxydation. As oxydes are formed of certain substances combined with oxygen, so many of the oxydes will yield abundance of oxygen-gas, as the oxydes of manganese, lead, and mercury. It is also obtained from nitre, which, in the language of modern chemistry, is called the nitrate of potash, being a compound of potash and nitric-acid.

Sulphur, a well known substance, is sometimes found in a state of purity, but more frequently mixed with other substances, particularly with metals; and in this state of combination the several substances are called pyrites: hence we have martial pyrites, and copper pyrites, according as the sulphur is in union with iron, or copper. Sulphur is insoluble in water, but when mixed with the earths and alkalies, the combination becomes soluble in water.

When combined with earths, alkalies, and metals, the new substances are called sulphurets; hence the sulphurets of potash. The alkaline sulphurets were formerly denominated *livers of sulphur*, from their colour, which resembles that of sulphur. Metallic sulphurets are found in the bowels of the earth in great abundance. Sulphur burns in proportion to the quantity of oxygen which combines with it; and according to the slowness or rapidity of the combustion, the products, if collected, will be found to be sulphur*ous* or sulphur*ic* acid.

Phosphorus is never found pure in nature, it is usually obtained from the phosphoric acid which exists in the bones of animals. It is a solid inflammable substance, that burns at a low temperature when exposed to the atmospheric air. At a temperature below 100° of Fahrenheit it undergoes a slow combustion, and burns with intense brilliancy at 160°; during which, it combines with the oxygen of the atmosphere, and is converted into phosphor*ous* or phosphor*ic* acid, according to the quantity of oxygen absorbed: it combines

with some of the earths and metals, forming with them phosphurets.

Carbon is the term applied to the base of the carbonic acid, as oxygen is the base of oxygen-gas. In a state of purity it is known only in the diamond, which is said to be crystallized carbon; because being dissipated with great heat in oxygen-gas, the result is carbonic-acid-gas, or a combination of pure carbon and oxygen. Charcoal is an oxyde of carbon, and its properties are: that it is a powerful antiseptic; has a great affinity for oxygen; is unalterable and indestructible by age; and if air and moisture be excluded, it is not affected by the most intense heat. Its antiseptic qualities render it useful in cleansing glass and other domestic utensils from offensive and long retained smells; in cleaning the teeth, and in depriving putrid water of its offensive taint. From its affinity to oxygen, it will decompose the sulphuric and nitric acids, the latter with great rapidity. "If," says Mr. Parkes, "the charcoal be dry, and finely powdered, and the acid very strong, and allowed to run down the inner side of the vessel to mix with the charcoal, it will burn rapidly, giving out a beautiful flame, and throwing up the powder so as to resemble a brilliant fire-work." Its indestructibility is clearly exhibited at Herculaneum, at the theatre of which, the beams were converted into charcoal by the lava which overflowed that city; and during the lapse of 1700 years, the charcoal remained as entire as if but newly formed.

Carbon unites with alkalies and metals, forming with them carburets: thus we have the carburet of iron, known in common language by the name of plumbago, or black lead. Steel is a carburet of iron, being a compound of iron, with a smaller portion of carbon.

Carbon exists in large proportions in bitumens and pit-coal: it is in fact their chief ingredient. Slates that are found in coals, contain from 10 to 40 per cent. of carbon. Carbon forms nearly the whole of the solid basis of all vegetables, and is a component part of sugar, wax, oils, gums, and resins.

Hydrogen cannot be obtained alone; but united to caloric, it forms hydrogen-gas, which is one of the constituents of water. It is plentifully distributed in nature, and acts an important part in the processes of animal and vegetable economy: it is one of the ingredients in oils, fat, ardent spirit, and ether. It forms a constituent principle of animal and vegetable acids, and of ammonia. It is the lightest of all the gases, and on that account it is generally used for filling air-balloons. It may be procured by putting some filings of zinc into a vessel, which has a glass tube adapted to it; then pouring upon them sulphuric acid diluted with 6 or 8 times its weight of water, an effervescence takes place, the water will be decomposed, the oxygen will combine with the metal, and the hydrogen-gas will be disengaged, and may be collected in a glass receiver adapted to the purpose.

Hydrogen-gas, like the atmospheric air, is invisible and elastic, and capable of indefinite compression and dilatation. It is incapable of supporting combustion or animal life. If the mouth of a phial containing hydrogen-gas, be brought near a candle, the gas will take fire, and burn gradually till it is all consumed; but if atmospheric air be mixed in the phial with the hydrogen-gas, it will explode; and if pure oxygen be mixed with it, they will explode, by being brought in contact with the flame of a candle, with a noise like that of a cannon. In the last two experiments, the phial should be made of very strong glass, and should, to prevent injury, be wrapped round with a handkerchief.

Hydrogen-gas, in whatever way it is obtained, always originates from water; either in consequence of a preceding composition, in which it had been combined with one of the substances employed; or from a decomposition of water actually taking place during the process.

Fill with hydrogen-gas, a bladder furnished with a stop cock, and adapt to it a common tobacco-pipe; dip the bowl of the pipe into a lather of soap, and turning the cock, blow up the lather into bubbles: these, instead of falling to the

ground, like those made of common soap-lather, will rise rapidly in the air.

Nitrogen, formerly denominated *Azote*, because it was destructive to human life, is lighter than atmospheric air, and incapable of supporting combustion. It enters into the combination of all animal substances, and is the base of nitric acid and ammonia. It is favourable to the growth of plants, and is probably the substance employed by nature in converting vegetables into animal substances.

Nitrogen-gas may be procured from iron filings mixed with sulphur, and moistened with water. This mixture is to be put into a large glass jar, and corked close: in a few days the oxygen will be absorbed by the mixture from the air which was previously in the glass, and the residuum will be pure nitrogen-gas. This gas has the following properties: 1. It is not absorbed by water. 2. It immediately extinguishes subtances in the act of combustion. 3. It is fatal to animals confined in it. 4. When mixed with pure oxygen-gas, in the proportion of four parts of the former to one of the latter, it produces a mixture resembling atmospheric air.

Metals are a class of simple bodies possessing very peculiar properties. The ancients did not rank any substance among their metals which was not malleable: the other bodies, that possessed similar characters except malleability, were called semi-metals, a term that is not now admitted into science. Till within a very few years, metals were characterized by their great specific gravity, lustre, opacity, fusibility, malleability, and ductility. Some metals are however neither malleable nor ductile; and the new metals discovered by Sir Humphry Davy, are even much lighter than water. Previously to his discoveries, metals were arranged in the following manner:

I. *The malleable metals:* Gold—Platinum—Silver—Palladium—Rhodium—Iridium—Osmium—Mercury—Copper—Iron—Lead—Tin—Nickel—Zinc.

II. *Brittle, and easily fusible:* Bismuth—Antimony—Tellurium—Arsenic.

III. *Brittle and fused with difficulty:* Cobalt—Manganese—Chromium—Molybdenum—Uranium—Tungsten.

IV. *Refractory:* Titanium—Columbium or Tantalum—Cerium.

Besides the foregoing metals, there are a number of others, discovered by Sir H. Davy, to which we have just referred; and which are the bases of some of the earths, and alkalies. Those from potash, soda, barytes, strontites, lime, and magnesia, have been obtained by means of the Voltaic battery; and they are named Potassium, Sodium, Barium, Strontium, Calcium, and Magnesium; of which we shall give a more detailed account farther on. The recent experiments of Dr. E. D. Clarke, of Cambridge, have pointed out a method of obtaining the bases of the earths, without the aid of electricity; and he has even succeeded in separating the metal of silex. From these experiments, there seems to be no doubt that the bases of all the earths are metallic: and should this be proved, the number of metallic bodies to be added to the above, including the bases of two of the alkalies, will be eleven.

Some metals are found pure, as Gold and Silver; and others are obtained from the bowels of the earth in a state of ore, combined with other metals, with sulphur, oxygen, or some of the acids. The ores are purified, and the metals obtained by *washing*, which frees them from all saline and alkaline matters; by *roasting*, which dissipates the sulphur; by *fusion*, the heat of which drives off the oxygen, which combines with the carbon used in the process, and the metal remains pure. The following properties of metals have been enumerated: 1. One of the most conspicuous is their brilliancy, which has been called the metallic lustre; by this property they reflect more light than any other bodies; which circumstance is supposed to depend in part upon the closeness of their texture, that renders them well adapted for mirrors, of which, in some shape or other, they always form the basis.

2. They are opake, or impervious to the light, even when reduced to extremely thin plates. But Sir Isaac Newton dis-

covered that gold-leaf the $\frac{1}{280,000}$th of an inch thick, transmitted the green coloured rays of light. This opacity makes part of their excellence as mirrors—brilliancy alone would not qualify them for that purpose.

3. They are fusible, by which property they may be cast into any shape whatever. Different metals differ exceedingly from each other, in their degree of fusibility. Mercury is always fluid in the common temperature of the atmosphere, while several other metals require the heat of the most intense furnaces to reduce them to the fluid state.

4. Their specific gravity, with the exception of the newly discovered metals, is much greater than that of any other body at present known. Antimony, almost the lightest, is six times heavier than water; gold is about nineteen times heavier; and platinum twenty-three times heavier than water. This is the heaviest of all the metals.

5. They are the best conductors of electricity and caloric.

6. They are not naturally very hard, but some of them may be hardened by art to such a degree, as to exceed the hardness of almost all bodies. Accordingly the cutting instruments of the moderns are made with steel; those of the ancients were formed of a combination of copper and tin. The elasticity of metals depends upon their hardness, and may be increased by the same means by which their hardness is increased.

7. Malleability is one of the most important properties of those metals to which it belongs—heat increases this property. Metals likewise become harder, and even denser, by repeated hammering.

8. Ductility belongs in a very high degree to some metals; by which is meant the capacity of being drawn out into wire, by being forced through holes, whose diameters are continually diminishing in size according to the fineness of the wire required. Ductility depends chiefly on the *tenacity* of the metals; by which is meant the power that a metallic wire has of resisting the action of a weight suspended from its extremity.

An iron wire $\frac{1}{10}$th of an inch in diameter, will support, without breaking, about 500lb.

9. When exposed to the action of heat and air, most of the metals lose their lustre, and are converted into substances more like earths than metals; these were formerly denominated calces, but are now called oxydes. If any of these oxydes are mixed with charcoal-powder, and exposed to a strong heat, in a proper vessel, they resume their metallic form.

10. All the metals are capable of combining with oxygen, and the new compounds are denominated metallic oxydes, and in some cases, metallic acids. They are also capable of combining with the simple combustibles; hence the combinations of a metal with sulphur, phosphorus, or carbon, are called sulphurets, phosphorets, and carburets of that metal.

11. They are capable of combining with each other, and of forming compounds that are extremely useful in the manufactures: thus pewter is a compound of lead and tin; brass is a compound of copper and zinc; bell-metal of copper and tin. These metallic compounds are called alloys, except when one of the combining metals is mercury; in that case the compound is denominated an amalgam.

If the compass of our work admitted of it, we should here give a description of each metal:—of the places in which they are all found:—of the modes by which they are obtained from the ores; and of the uses to which they are applied in the arts and manufactures; but for these we must refer our readers to works in which they are treated of at length. See particularly Jameson's System of Mineralogy, 3 vols. 8vo. second edition.

Of the Earths. The term earth in chemistry, is applied to a few bodies, which, till within these seven or eight years, were all regarded as simple substances; and from the different combinations of which, all those substances are formed, which are usually classed as earths and stones. They consist of *Lime*, *Magnesia*, *Barytes*, *Strontites*; which are called *Alkaline* earths, as agreeing with the alkalies in some of their properties:

and *Alumina*, *Glycina*, *Zirconia*, *Silica*, *Yttria*; which are earths *proper*. They all agree in the following properties: 1. They are insoluble, or nearly so, in water, especially when combined with carbonic acid. 2. They give little or no taste or smell. 3. They are fixed, incombustible, and incapable of being altered by the fire. 4. Their specific gravity is less than five times that of water. 5. When pure, they are capable of assuming the form of white powder. 6. They are not altered when heated with combustibles in our hotter furnaces. The alkaline earths have a very near resemblance to fixed alkalies, and seem to form the connecting link between these and the proper earths. They are distinguished by the property of giving a green colour to vegetable blues, and of neutralizing acids. Of the principal earths, we shall mention a few particulars.

Lime is always found in combination, and generally with carbonic-acid, in chalk and marble, as well as in lime-stone: it may be obtained very pure by means of great heat, which drives off the acid-gas and water, leaving the lime as a product. Lime owes its property of hardening in water, to its great attraction for that fluid and carbonic-acid; for being mixed with water, it crystallizes as it imbibes the carbonic acid, and if well made, becomes as hard as marble. The sand usually mixed with the lime, serves a purpose similar to that which is answered by sticks put into saline, or saccharine solutions, to assist in the crystallization. The use of lime, in agriculture, is thought to be its property of hastening the dissolution of all vegetable and animal matters, and of imparting to the soil a power of retaining its moisture. It is used in tanning, to remove the hair, and dissolve the gelatinous part of the skin; in the manufacture of sugar, to deprive the composition of the excess of its acid; and in the manufacture of soap, to render the alkali a more powerful caustic. Lime, combined with sulphuric acid, forms gypsum, or plaster of Paris —with fluoric acid, it gives fluor, or Derbyshire spar. It is found united with phosphoric acid, in different minerals; and the bones of adult animals are formed chiefly of lime

and phosphoric acid, in the proportion of 80 parts of lime, and 20 of acid.

Magnesia is a soft white earth, with scarcely any taste or smell; but when combined with sulphuric acid, it forms a salt easily dissolved: this is called the sulphate of magnesia, or the Epsom salts of the shops. Magnesia is not found in a state of purity, but is generally procured from the sulphate, which exists in great abundance in sea-water, and in many mineral springs, as they are denominated. It is used in chemical processes, and in medicine, is employed in enamelling, and in the manufacture of porcelain.

Alumina, sometimes denominated argil, derives its *first* name, as being the basis of alum; its second, because it is the basis of the clays. It is found in a crystallized state in the sapphire: it makes a considerable part of the differently coloured ochres. Common clay is a mixture of alumina and silex; so also is fuller's earth: and owing to the affinity which alumina has for greasy substances, it is extremely useful in scouring cloth. Alumina and silex, are the chief materials in brick-making, and in the manufactory of all kinds of pottery. It is employed by the dyer and calico-printer as a mordant for fixing the colours.

Silica is generally found in a stony state, and from its forming nearly the entire composition of flint, it has acquired the name of Silex or Silica: it exists in great abundance in agates, jasper, quartz, and rock crystal. It is nearly infusible, *per se,* but with soda or potash, it runs readily into glass, and is used in the manufacture of this substance, porcelain, &c.

ALKALIES; of these there are three different species, named potash, soda, and ammonia: the first two are called *fixed* alkalies, because they require great heat, in order to be melted and dissipated: the ammonia is extremely volatile, and quickly evaporated at the common temperature of the atmosphere. Alkalies have the following properties: they have a peculiar acrid taste, and act with so much energy, that they corrode the tongue.—They have the power of changing the blue colours of

vegetables to green.—They are soluble in water, and give out heat during the mixture.—They corrode, and, if sufficiently powerful, reduce woollen cloth to the form of a jelly.—They render oils miscible with water, by uniting with them, and forming thereby soaps.—Combined with sulphur they form alkaline hepars or livers, now denominated sulphurets; and with acids they form neutral salts, distinguished by different names, according to the acid and alkali that enter into their union; hence we have the sulphate of potash, compounded of sulphuric acid and potash; the nitrate of soda, formed of nitric acid and soda, &c.

Potash is a dry, solid, white, crystallized substance, fusible at a high temperature, very deliquescent; and, when combined with silex in fusion, the compound is glass. It is procured from the burnt ashes of vegetables by combustion in iron or other pots, whence the compound word pot-ash. It was known under the name of vegetable alkali, in consequence of its being chiefly obtained from plants.

Soda is usually procured from the ashes of sea-weeds, or marine plants, but chiefly from the salt water of the sea, soda being one of the constituents of sea-salt. It is found in large quantities combined with carbonic-acid in different parts of the earth, especially in Egypt, hence its name *mineral alkali*; and common culinary salt is a compound of soda and muriatic-acid. But the soda of commerce is obtained from ashes of different species of salsola, a genus of plants that grow upon the sea-shore. Almost all the algæ, or sea-weeds, contain a considerable quantity of soda, and the ashes of those plants are known in this country by the name of kelp. The fixed alkalies are used in medicine, as caustics in surgery; for if a piece of flesh be put into a strong solution of potash, or soda, it will be soon dissolved: they are used in the manufacture of glass, in soap-making, in dyeing, and in the formation of various colours for painting; also in the manufacture of alum, and in bleaching. The potash used in this country, is chiefly brought from America and Russia; but the kelp of our own

coasts, and the barilla of Spain and Sicily, furnish us with the greater part of our mineral alkali.

Ammonia, or volatile alkali, exists in its most simple state in gas: it has a great affinity for water, with which it readily combines, and forms liquid ammonia. It is a compound of hydrogen and nitrogen; but the singular fact discovered by Berzelius and Pontin, that ammonia and mercury, by the aid of a Voltaic battery, form an amalgam, induced Sir Humphry Davy to consider the base of this alkali as a metallic substance: an idea which is, however, rejected by other eminent chemists. Ammonia is given out by all animal and vegetable substances when in a state of putrefaction; but it is chiefly procured by a dry distillation of bones and horns. It is used in medicine, in dyeing, and in the manufacture of sal-ammoniac, or, as it is called in chemical language, the muriate of ammonia; for the muriatic-acid and ammonia, in a state of gas, unite and form a solid.

ACIDS have the property of changing the blue vegetables to red: they, for the most part, combine readily with water, and, when united with the earths, alkalies and metallic oxydes, produce salts. In general, acids are in the state of liquids: but some of them are solid, as the Benzoic acid; and some are met with in a state of gas, as the carbonic and muriatic acids. Some are mild, others are corrosive; some are pungent and volatile, others are fixed and inodorous. Acids are formed by the combination of certain substances with oxygen, which is, in most cases, unquestionably the acidifying principle; on that account the name *oxygen* was assumed from the Greek words οξυς and γινομαι, signifying to produce acidity.

Acids, as we have seen, may exist in three states, which are caused by the different degrees in which the base is combined with oxygen. In the first they contain the least possible quantity of oxygen to render them acid; in this state they are designated, in the chemical nomenclature, by the termination *ous*: thus we have the sulphur*ous*, the phosphor*ous*, and the nitr*ous* acids. In the second state they contain a

larger portion of oxygen, and are in general saturated with it: this state is expressed by the termination *ic*, as the sulphur*ic*, nitr*ic*, phosphor*ic* and acet*ic* acids. In the third state, which belongs to but few, 'they contain an excess of oxygen; and are distinguished by the prefix *oxy*, as in the case of the *oxy*-muriatic-acid.

When metallic or other substances are combined with a less proportion of oxygen than is sufficient to render them acid, they are said to be oxydated, and the substances are called oxydes. Formerly acids were divided into the mineral, vegetable, and animal, according as they were supposed to derive their origin; but it is now usual to class them according to the number of principles, or simple substances, of which they are composed: the acids of the *first class* contain only *two* principles, viz. oxygen, and some substance called the radical, as the sulphur*ic* and sulphur*ous* acids are formed of the radical sulphur, and a greater or less quantity of oxygen; those of the *second class* are composed chiefly of oxygen, hydrogen, and carbon, in different proportions. Some of them contain a portion of nitrogen.

Many of the acids are found in great abundance in nature, but in combination with other substances: thus the vast masses of limestone, chalk, and marble, found in every part of the world, are combinations of lime and carbonic acid; Gypsum, of which there is so much in different parts of the globe, is composed of lime and sulphuric acid; the fluor spar, so abundant in Derbyshire and other places, is a compound of fluoric acid and lime; and the constituents of common culinary salt, which is found in such immense quantities, both in the old and new world, are muriatic-acid and soda.

CHAP. VII.

CHEMISTRY,

Continued.

Chemical attraction or affinity illustrated: Chemical apparatus—Experiments—Decomposition of the fixed alkalies.

CHEMISTRY is a science depending on experiments which are chiefly founded on very simple laws, that ought to be well understood in the outset of the study. The different actions which result from the proper application of the bodies already enumerated, whether taken in their simple state, or combined, are founded on certain agencies which apparently exist in all matter. Of these the unknown causes are denominated attraction and repulsion. We have already explained what philosophers mean by these terms in Electricity, Voltaism and Magnetism, without pretending to guess even at the causes which produce them. In chemistry, the term attraction is frequently or generally exchanged for that of affinity. There are, however, some writers who make a distinction between the terms. Chemical affinity with them is to be regarded as the principle of chemical action; and chemical attraction as the same principle in a state of operation, by which alone the degree of affinity can be measured; for the affinity still exists, whether the attraction be in action or not.

The terms are, however, frequently taken without this distinction, and chemical or elective affinity, are often employed to express the very same ideas. The term attraction, when used generally, and without limitation, as has been already observed, denotes the principle which brings, or has a tendency to bring bodies remotely situated, to one another. Such is the action subsisting between the earth, and bodies that tend to fall to its surface: such is the action between the planets and their satellites, and between the sun and planets; and probably the same principle extends to all the fixed stars, and the indefinite number of planets depending upon them, as the earth, and other planets known to us, depend upon the sun. This principle, then, it may be assumed, acts, at indefinitely great distances, in comparison of which the distance between the Georgium Sidus and the sun, though 1,800,000,000 miles, can be regarded only as a point. But chemical, or elective affinity or attraction, acts only upon particles at imperceptibly small distances. The following experiment will illustrate the idea of what is intended by chemical affinity.

Ex. 1. A spoonful of salt, thrown into a vessel of water, very soon diffuses itself through the whole of the fluid, and the salt is said to be combined with the water; the water and the salt have a certain affinity for each other, and they cannot be separated by any mechanical means: but if another substance be introduced, to which water has a greater affinity than it has to the salt, it will quit the salt, to unite to this third substance. If, therefore, alcohol be the third body, the water will leave the salt to join the spirit; and the salt, by its superior gravity, will fall to the bottom of the vessel.

Ex. 2. Alcohol will dissolve camphor, and the fluid be perfectly clear, which is another instance of chemical combination: the two substances have a strong affinity for each other: but the spirit has a still stronger affinity for water than for the camphor; and if a little of that fluid be added to the solution, the camphor will fall down in flakes, that is, in a solid form.—The following instance of the nature of simple

affinity is given in almost all the elementary treatises on the subject.

Ex. 3. To some acetate of soda, put into a retort, G, Plate VI. fig. 2, add muriatic acid, and distil the mixture to dryness. The fire will drive off the acetic acid, but will have no effect on the muriatic acid, while in combination with the soda, which proves that the soda has a greater affinity for muriatic acid, than it has for the acetic. If now nitric acid be addded to the *muriate of soda*, for such is the name of the new substance, and heat applied, the muriatic acid will be driven off, the nitric acid is combined in chemical union to the soda, and the substance is now a nitrate of soda; to which, if sulphuric acid be added, and heat again applied, the nitric acid will be expelled, and the sulphuric acid will unite with the soda, forming a true sulphate of soda. These changes all take place in consequence of chemical affinity.

Hence we have the method adopted in forming the tables of elective attractions. After what has been said, their construction is extremely simple; the following is a specimen with regard to three different substances.

SODA.	LIME.	MURIATIC ACID.
Sulphuric acid.	Oxalic acid.	Barytes.
Nitric acid:	Sulphuric acid.	Potash.
Muriatic acid.	Tartaric acid.	Soda.
Fluoric acid.	Phosphoric acid.	Lime.
Phosphoric acid.	Nitric acid.	Ammonia.
Acetic acid.	Muriatic acid.	Magnesia.

These tables are given only as a specimen: not half the substances are enumerated, for which the soda, the lime, and the muriatic acid, have an affinity, but these will serve to explain the principle, which is as follows. The substance whose attractions or affinities are to be enumerated, is placed at the head of the column, and the different substances for which it has an affinity, are placed beneath it, in the order of the

forces of affinity, the substance to which it has the strongest affinity being immediately under it, the others following in that order, and the one, for which it has the least or weakest affinity, being the lowest in the column. Hence, as in the last experiment, the muriate of lime, which is a compound of muriatic acid and lime, will be decomposed by any of the other acids standing above the muriatic acid in the second column: and the muriate of magnesia, will be decomposed by ammonia, or the other substances above it, in the third column. But if to a sulphate of lime be added nitric acid, which stands below the sulphuric acid, no decomposition will be produced, because the sulphuric acid has a stronger affinity for lime than the nitric acid.

We shall illustrate the subject of chemical affinity still farther, and observe: 1. That it acts only in the case of bodies of different natures. Mix together soda and sulphuric acid; they are both highly acrid substances, but of opposite qualities: but by chemical affinity they combine, and form a neutral salt, called Glauber's salt, or sulphate of soda.

2. Chemical affinity acts only between the minute particles of bodies. A lump of sulphur thrown into alcohol will cause no action, but if the sulphur be brought into very fine powder by sublimation, the bodies will unite, and the solution be perfectly transparent.

The union of the sulphur with the alcohol is thus effected. Put some pounded sulphur into a retort, A, see Plate VI. fig. 7; suspend within it, a bottle, B, containing alcohol; and when the whole is covered with another glass, C, and the joinings well luted, then heat the apparatus by means of the furnace, F. The sulphur will now rise up in small particles, that is, it will be sublimed, and will unite with the particles of alcohol, which also are driven off by the heat, and the two bodies thus united will fall into the matrass, x.

To prove that the transparent fluid is a true solution of sulphur in the spirit, pour a small portion of it into a wine-glass, and add to it some distilled water; the alcohol having a stronger

affinity for water than for sulphur, will leave the latter to unite with the former, and the sulphur will fall to the bottom.

Flowers of sulphur are the product of sulphur, sublimed in the dry state: that beautiful substance, flowers of Benzoin, are obtained also from the sublimation of Benzoin by a similar method.

3. This attraction may take place between several bodies: thus, two, three, or more metals may be fused together, so as to produce compounds, the properties of which are very different from those of the constituent parts. Melt eight parts of bismuth, five of lead, and three of tin together, and though either of the metals separately, requires a great degree of heat to fuse it, yet when united, the compound is so fusible, that a spoon made of it will melt in boiling water. A composition of equal parts of lead, zinc, and bismuth, may be kept in fusion upon a paper held over the flame of a candle.

4. Bodies in general will not unite chemically unless one of them at least be in a fluid state. Neither sugar nor salt will combine with ice, but they most readily unite with water. Alkali and sand in their usual state have no action upon one another; but when the alkali is reduced by a violent heat into a fluid state, the two substances run into the compound glass.

5. When two or more bodies are united by this affinity, their temperature suffers a change at the instant of union. In a small phial, half full of cold water, pour some sulphuric acid very gradually, and a sensation of heat will be immediately perceived, which by the continual addition of acid, may be increased beyond that of boiling water. Great care must be taken to pour the acid in gradually.

Mixture does not necessarily produce heat: in some cases it causes a most intense cold. Hold in one hand a phial, containing some pulverized muriate of ammonia, upon which pour cold water, and shake the mixture; a sensation of great cold will be immediately felt. The causes of these effects are thus explained. When substances become more *condensed* by mixture, heat is evolved; and when they expand, cold is

produced: that is, the compounds have a greater or less capacity for caloric, than the separate ingredients. The principle is farther illustrated by the following experiment. In a cup, containing a small quantity of oil of turpentine, pour half as much strong nitrous acid, previously mixed with a few drops of sulphuric acid. The moment the acids come in contact with the turpentine, a violent flame will be produced, which is owing to the compound having a much less capacity for caloric than the separate fluids, consequently a part is liberated, and the rapidity with which it is evolved, causes the inflammation. This is a hazardous experiment, the turpentine should be placed in the opening of a chimney, and the acids in a phial tied to the end of a stick five or six feet long, from which it may be poured at arm's length.

6. By chemical affinity some bodies acquire qualities very different from those which the compounding bodies had before. Iron and tin may be combined by fusion. Separately, both metals are malleable and ductile, but the compound has lost both these properties, and has become extremely brittle. Liquid ammonia, and concentrated muriatic acid, which have, separately, most pungent odours, by mixture in due proportions, lose their scent entirely. If concentrated sulphuric acid be dropped gradually into a saturated solution of muriate of lime, a solid will be formed from the two fluids. The same effect will be produced with muriate of lime and carbonate of potash: or with a saturated solution of sulphate of magnesia, (Epsom salt,) mix a like solution of caustic alkali, and the mixture will immediately become almost solid. Equal parts of crystallized nitrate of ammonia and sulphate of soda, triturated together, will become fluid.

7. The action of two compound substances, by which they mutually decompose each other, and produce two or more new substances, is called compound affinity.

If to a solution of sulphate of ammonia, there be poured nitric acid, no decomposition takes place, because the sulphuric acid has a greater affinity for ammonia than nitric acid.

But, if instead of the nitric acid, a solution of nitrate of potash be poured in, a double decomposition takes place, and by evaporation two new bodies are obtained, viz. a sulphate of potash, and nitrate of ammonia. For in this case the sulphuric acid of the sulphate of ammonia, leaves the ammonia to seize upon the potash, and, at the same time, the nitric acid attracts the ammonia.

The acetate of alumina, used by dyers and calico printers, is not readily formed by directly uniting acetic acid and alumina; for the affinity of these substances for each other is but weak. But if the sulphate of alumina be mixed with the acetate of lead, a mutual decomposition takes place, and the acetic acid of the acetate of lead unites with the alumina, and thus the required article is obtained.

Having given this brief view of some of the chief phenomena and principles of chemical affinity, we proceed to notice a few articles of the more simple and familiar apparatus necessary to a young chemist; connecting with them such experiments, as may, if put in practice, render the subject easy and interesting.

For the mechanical division of bodies, it is requisite that the practical chemist should have hammers, knives, files, and rasps, for breaking, cutting, rasping, filing, and shaving: he should have pestles and mortars for pounding; a stone and muller for levigating; a pair of rollers for laminating metals; a small forge, lamps and furnaces of various descriptions. The following apparatus will be sufficient for the illustration of the early principles of the science. In Pl. VI. fig. 1, is a tub, or trough, AZ, nearly full of water, with a shelf, KKK in it; B, G, F, are glass jars or receivers, inverted with their mouths downwards. We shall point out its use by the example of Oxygen-gas. C is a glass bottle, into which are put some red-lead, or black oxyde of manganese, and a small quantity of dilute sulphuric acid. D is a glass tube, generally fitted, by grinding, to the neck of the bottle, and curved so as to enter conveniently below the shelf, and communicating with

one of the jars or receivers B, G, F. E is a glass retort, such as is shewn in figure 5, which may be applied to the same purpose. If the bottom of the bottle C be heated by means of a wax taper, or common candle, the oxygen-gas will rise in bubbles, and fill the receiver, from which it drives out the water.

Fig. 2. Represents an elegant chemical apparatus of the same nature, used by Sir H. Davy, the professor of chemistry, at the Royal Institution.

A, is a japanned tin vessel, filled within two or three inches of the top with water. Just below the surface of the water is fixed a shelf, having several holes bored through it, to which small funnels are attached underneath. The glass receiver B, intended to receive the gas, is filled with water, and being inverted with its mouth under water, it is raised up gently, and placed upon the shelf over one of the holes, where it will remain full of water, which is kept up by the pressure of the atmosphere, in the same way as the mercury is retained in the tube of a barometer.

The materials from which the gas is to be disengaged, are put into the retort G, which is passed through and suspended in one of the rings of the lamp-furnace. AE is an improved Argand's lamp, having two concentric wicks, placed on a shelf, which is moveable up and down to bring the lamp to a convenient distance from the retort. The lamp is to be lighted, and as soon as the substances in the retort act upon each other, the gas will begin to be disengaged, and will ascend through the hole of the shelf into the vessel B, and displace or force down the water with which it had been filled. When the water is displaced, the receiver is full of gas, which may be preserved in it, by keeping its mouth always under water in the cistern.

The gas so obtained may be transferred from the vessel B to any other, in the following manner: fill the vessel into which the gas is to be transferred, with the fluid in the trough, and place it on the shelf, over one of the holes. Then take the vessel B, and, keeping its mouth still under the fluid,

bring it beneath the hole above which the vessel to be filled is placed; then by depressing its bottom, and elevating its mouth so as to bring it to an horizontal position, the gas in it will escape, and rise up through the hole, on which the other has been placed, and will fill it, by displacing the water.

When the gas to be procured is absorbed by water, as carbonic-acid-gas, quicksilver is used instead of water, to fill the trough, and a much smaller vessel than A, made of stone or wood is used. See fig. 6. described in p. 173.

A small glass vessel, capable of containing an ounce measure, is used for measuring gases; if this phial be successively filled, and emptied under a larger jar, we may thereby throw into that jar whatever quantity of gases, or any mixture of them, we please.

Adjoining the receiver B, and on the shelf, fig. 2, is a strong glass tube, for receiving a mixture of gases, intended to be exploded by means of the electrical sparks. Near the upper end, which is closed, two pieces of brass wire pass in the tube; they are cemented in, so as to make the holes air-tight, and they nearly touch each other within the tube. If the interval between the two wires be made a part of the electric circuit, by putting chains, connected with a Leyden phial, to the hooked ends of the wires, the electric spark will pass through the interrupted space between the two wires, and explode the gases.

Exp. 1. Pour sulphuric acid upon a small quantity of mercury, in the glass retort, fig. 2, and apply the heat of the lamp, and sulphurous-acid-gas will be evolved; for the mercury combines with part of the oxygen of the acid, which having lost a portion of its oxygen, is converted into sulphurous acid in the shape of gas.

Exp. 2. To copper filings or shreds, put, in the retort, fig. 2, some nitric acid, diluted with three times its weight of water, and nitric oxyde or nitric gas will be evolved. The same gas will be given out from iron filings and nitric acid: for the acid will, in part, be decomposed, and its oxygen will render the metal soluble.

Exp. 3. Nitric acid may be obtained by distilling in the

retort G, fig. 2, two ounces of nitre, and one part of sulphuric acid, and collecting the gas in proper receivers. In a fluid state, it is clear and colourless, like water: its smell is acrid, and its action on animal substances, very corrosive. It stains the skin permanently with a yellow colour. It has a great affinity for water, and oxydizes most of the metals.

Nitric acid is composed of twenty-five parts of nitrogen and seventy-five of oxygen: whereas the atmospheric air is a compound of the same materials, with the proportions reversed; it being formed of about twenty parts of oxygen to eighty of nitrogen: the latter is not only perfectly innocent, but necessary to the existence of animal life; the former a most corrosive and destructive liquid.

Exp. 4. If a mixture of the nitrogen and oxygen gases, in the proportions of 25 to 75, be introduced into the tube x in fig. 2, and a number of electrical explosions be passed through it by means of the wires at a, the gases will unite, and nitric acid will be produced.

Exp. 5. Nitrous acid may be obtained by heat from the lamp, fig. 2, by pouring sulphuric acid on some nitrate of potash.

Muriate of soda treated in the same manner, will give out muriatic acid, in the shape of gas.

Exp. 6. Into the glass retort G, fig. 2, put a mixture of two ounces of lime, and one of muriate of ammonia, (sal-ammoniac,) both in powder, apply the lamp, and ammoniacal gas will come over, but it must be collected over mercury, on account of its affinity to water. This kind of gas may be procured by heating liquid ammonia, and collecting the gas. The usual test to discover the presence of ammonia is the muriatic or acetic acid. If either of these be held over any thing giving out ammonia, white fumes appear, which are owing to the ammonia uniting with the acid, and forming a cloud, which is a neutral salt.

Fig. 3. Represents a retort used in distillation. It is a vessel either of glass, or of baked earth, for containing the

liquor to be distilled. When it has a small neck *a*, with a stopple fixed to it, for introducing the materials through, it is called a tubulated retort. B is the receiver for condensing the vapour which is raised, and into which the neck of the retort is inserted. The joining *b*, is made air-tight by some substance, such as paste, applied to it, called in chemistry luting.

When great heat is employed, earthern retorts are used, and they are placed on a fire. When a less heat is wanted, glass retorts are used, which are suspended over a lamp. The receiver B is placed on some stand, which will keep it steady.

Exp. 7. Pour four ounces of water into a retort G, fig. 2, and add to it some solution of potash, and raise it, by means of the lamp, to a boiling heat. When it boils, drop in through a tubulure, as at *a*, fig. 3, a small piece of phosphorus. The water will now be decomposed, and the hydrogen combining with the phosphorus, we have phosphuretted hydrogen-gas, of which the bubbles, as they come to the surface of the water, burn with great rapidity. This is the most combustible substance known.

Fig. 4. A, is a chemical vessel, called a matrass, used for distillation also, having a vessel B called an alembic, fitted to the head. The liquid, raised by heat into the state of vapour, is condensed in the alembic, and falls into a groove all round its inside, whence it runs out by the spout C into the receiver D.

Fig. 5. Is a phial with a bent glass tube fitted into it, for disengaging gases in the pneumatic apparatus.

Exp. 1. Put into a glass vessel A, fig. 5, an ounce or two of marble, broken down into small bits, and about an equal quantity of water, on which pour a small quantity of sulphuric acid, then put in the tube *z*, through which the carbonic acid will proceed, and may be collected in any of the receivers shewn in fig. 1. In this case, the lime in the marble has a stronger affinity to the sulphuric acid, than it has for the

carbonic acid in its original composition—it leaves the latter therefore to seize upon the former.

Exp. 2. Put into the vessel, fig. 5, an ounce of iron filings, with three or four ounces of water, and pour upon them a little sulphuric acid, and hydrogen gas will be evolved. In this case the water is decomposed: the oxygen unites itself to the metal, and the hydrogen escapes, and may be conveyed by the glass tube *z* into any proper receiver.

Exp. 3. A better mode of obtaining hydrogen-gas is from the filings of zinc, upon which is to be poured sulphuric acid, diluted with six or eight times its quantity of water: the same kind of vessel is used as in the last experiment. This gas, as has been already observed, can be procured pure only from water, which in all cases suffers a decomposition.

Exp. 4. Into a jar *x*, fig. 6, containing ammoniacal gas, admit from the retort *z*, some muriatic-acid-gas, and the two invisible gases will combine, and form a solid, muriate of ammonia, or sal-ammoniac, which is deposited upon the sides of the vessel. Here two of the most pungent and volatile substances known, combine and form a solid, almost without smell, and of little volatility. The theory on which the experiment depends, is, that the bases of the gases, that is, the ammonia and muriatic acid, have a greater affinity for each other, than they have for their caloric; they accordingly give out a portion of caloric, and unite into one mass.

Exp. 5. By a similar mode, convey carbonic-acid-gas into the jar *x*, containing ammoniacal gas, and the solid carbonate of ammonia will be formed on the inner surface of the jar, in a kind of silky fibres, or fine powder, which must be regarded as crystals.

Exp. 6. Put an ounce of black oxyde of manganese into a small glass retort G, fig. 5, and pour upon it a little concentrated sulphuric acid; then apply the lamp, as in fig. 2, and the gas will be collected in the receiver B. A pound of the oxyde of manganese will furnish ten gallons of gas.

Fig. 6. is an apparatus contrived to collect such gas as cannot be received over water. The box contains mercury, and is used in every respect like the apparatus, fig. 1.

Put some pieces of sulphur into the vessel A C, to which the receiver, fig. 7, is fitted, and accurately luted round. A is put on a vessel filled with sand, called a sand-bath, which is to be heated by the furnace F. The sulphur melts, a thick white smoke arises, which is deposited in C, in the form of powder. Hence it is called flowers of sulphur. The earthy matter is left behind, and the sublimed sulphur is pure. In this experiment, the matrass *x*, and the extended tube to *o r*, belonging to C, are supposed to be away.

Fig. 8. is a crucible. Crucibles are generally made of baked clay, or a mixture of clay, and black lead in powder, which renders them capable of sustaining an intense heat. When used for melting substances, they have generally covers adapted to them, as is shewn in the figure.

Fig. 9. is called a philosophical candle, which is exhibited by setting fire to hydrogen-gas. A B is a glass jar, containing iron filings, and diluted sulphuric acid; *a* is an additional neck, with a stopper, by which a fresh supply of iron filings and sulphuric acid may be readily introduced; *b x* is a piece of tobacco-pipe, fixed into the cork or stopper *b*, of the jar A B.

Fig. 10. is the representation of the combustion of iron in oxygen-gas. A is the iron wire supposed to be in a state of inflammation, B C is a glass jar containing oxygen-gas placed in a vessel containing water. This experiment was contrived by Dr. Ingenhouz.

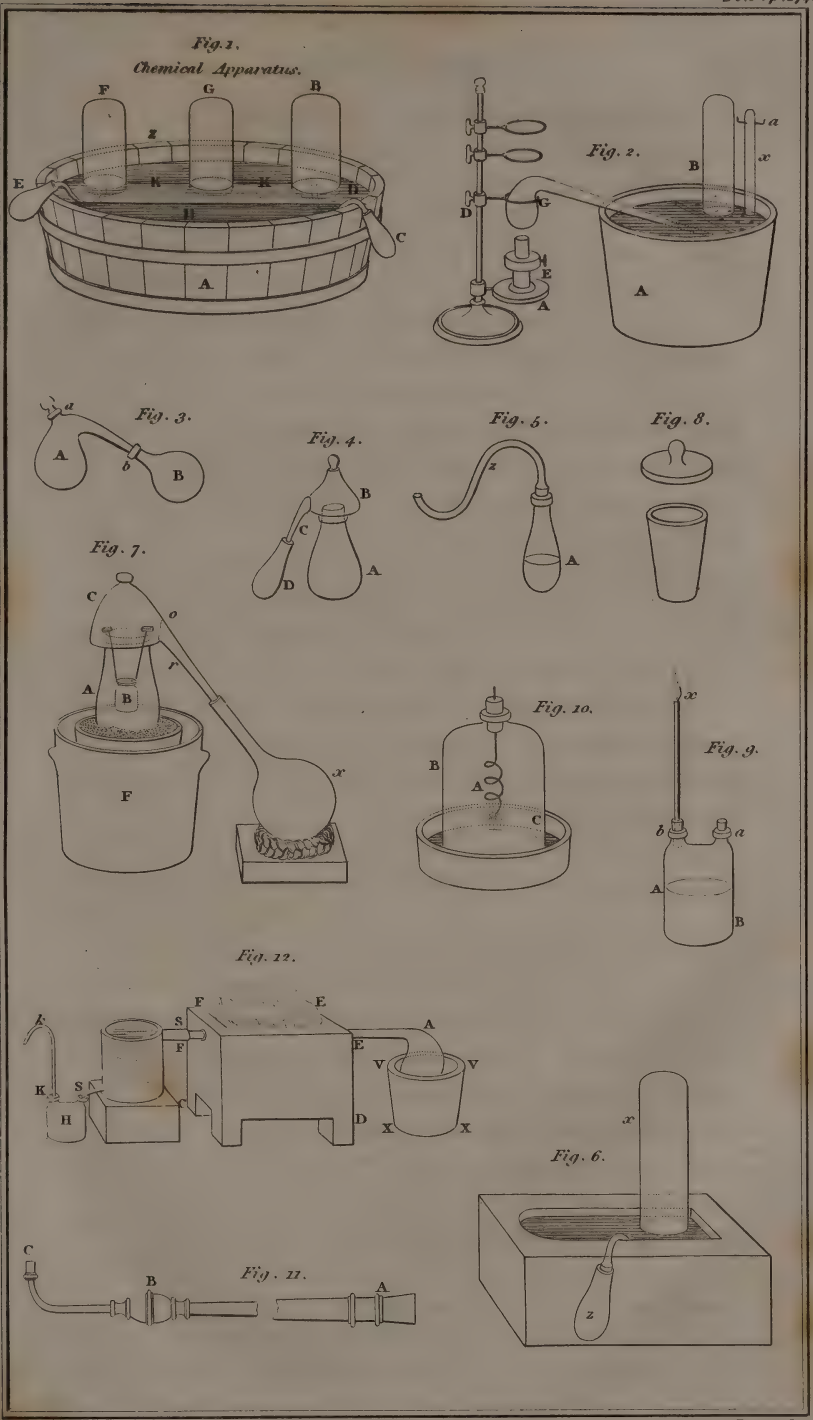
Fig. 11. represents a blow-pipe eight or nine inches long. It is made of brass or silver, the mouth-piece A, should be of ivory, the hollow globe B, is contrived to condense the vapours coming from the breath; the opening C, through which the wind is applied to the flame, must be as small as the finest wire.

Fig. 12. *Decomposition of Water.*—E F is a tube of com-

mon glass, made very strong and thick, about an inch in diameter. CFED is a furnace of iron, containing lighted charcoal; A is a glass retort, containing water, and resting on a small surface V V. To the lower extremity of the glass tube, a worm S S is applied, connected with the flask H, which has two necks, or orifices. To this flask, a glass tube K k is adapted, in order to convey the gas formed, to any proper vessel for receiving it. When the apparatus is thus arranged, introduce into the glass tube E F, a quantity of iron filings, and fill the retort A, with water. The fire being then lighted both under the tube and under the retort, the glass tube will become red hot, and the water in A will boil and rise through the iron filings in a state of vapour. The iron absorbs the oxygen of the water, and becomes oxydized. The hydrogen of the water passes through the worm S S into H, and from thence rises in the state of gas, into the tube K k, to which a bladder, or other receiver, may be applied, in order to obtain it. When the apparatus is cooled, the iron filings will be found to weigh much heavier, than when first put in, from the quantity of oxygen they have absorbed; and in this state they exhibit a true oxyde of iron.

Miscellaneous Experiments. Exp. 1. To an ounce of diluted nitrous acid in a wine-glass, put half an ounce of mercury. The acid will be decomposed, and during the process it will change colour from the yellow to the green, blood red, &c. till it become pale as water. Here is a metal dissolved in a fluid, and the opacity of the metallic body is completely overcome, the liquid being perfectly transparent. If more mercury be added, and heat applied to evaporate part of the water, the newly formed substance will shoot into prismatic crystals, exhibiting the formation of a metallic salt, the nitrate of mercury.

Exp. 2. On an ounce of a solution of potash, pour half an ounce of sulphuric acid, and, after a while, crystals of sulphate of potash will be formed.



Lowry Sc.

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An ounce of muriatic acid, poured on the same quantity of caustic soda, will produce common culinary salt.

Exp. 3. Pour a little lime-water into a wine-glass, and some solution of oxalate of ammonia, which is a compound of oxalic acid and ammonia: both are transparent, but being mixed together, the oxalic acid seizes on the lime, and produces a white precipitate of oxalate of lime.

Carbonic-acid-gas thrown into lime-water, will yield a precipitate in the form of carbonate of lime.

Exp. 4. Take two glasses of pure water, and with one mix a single drop of sulphuric acid: pour a little muriate of barytes into the other, and no change will take place: pour some of the muriate into the other glass, and the barytes will leave the muriatic acid to combine with the sulphuric, for which it has a greater affinity, and a sulphate of barytes is now formed, as a white precipitate.

Exp. 5. Instead of the muriate of barytes, make use of the nitrate of silver: and sulphate of silver will be formed.

Exp. 6. Mix an ounce of litharge of lead with a dram of muriate of ammonia reduced to powder, and heat the mixture in a clean tobacco-pipe: the ammonia will be driven off in the form of gas, and the acid will combine with the lead, forming the muriate of lead, which, when ground, is the true patent yellow.

Exp. 7. To an ounce of red-lead, add a dram or less of fine charcoal powder, and being well incorporated in a mortar, put the mixture in a tobacco-pipe, and bring it to the action of an intense heat in a common fire: the result will be metallic lead, for the oxygen of the lead combining with the carbon, and a portion of caloric, goes off in the shape of carbonic-acid-gas, and the metal is of course left pure. The usual mode of reducing metallic oxydes, is to mix them with charcoal, and subject the mixture to an intense heat, by means of a crucible, see fig. 8.

Exp. 8. Take some red-lead, and expose it to an intense heat in a crucible, fig. 8, and the result will be a metallic glass, which furnishes an example of the vitrification of

metals, and of the method of glazing different kinds of pottery.

Exp. 9. Spread a piece of tin-foil upon a piece of thick cartridge paper: pour a small quantity of strong solution of nitrate of copper upon it. Fold it up quickly, and wrap it round with another paper, to exclude the access of the atmospheric air. Place it on a tile, marble, &c. and in a little while combustion will commence.

Exp. 10. By mixing together in a warm mortar, three parts of nitre, two of potash, and one of sulphur, we have a fulminating powder. A small portion of this placed in a fire-shovel over a hot fire, blackens, melts, and explodes with a violent report, but without danger.

Exp. 11. To shew the effect of the atmospheric air upon crystallization, dissolve three drams of sulphate of soda (Glauber's salt) in an ounce of boiling water, pour it, while hot, into a phial, and cork it close. It will remain in this state any length of time, but if the cork be removed, the crystallization will commence and continue. This experiment will answer with the saturated solution of many other salts.

Exp. 12. If the experiment be repeated with a small thermometer immersed in the solution, and closed so as to exclude the atmospheric air, it will be seen that the mercury will rise on the removal of the cork; which proves, that caloric is given out in the transmutation of liquids into solids. It agrees with the law discovered by Dr. Black, viz. that *whenever a body changes its state, either from a solid form to a fluid, or vice versa, it either combines with, or gives out caloric:* that is,

1. Every body which passes from the solid to the liquid state, absorbs a portion of heat, which exists in a true state of combination, and is called *latent* heat. If a pound of water at 32° be mixed with an equal quantity at 172°, the temperature of the mixture will be $\frac{32^\circ + 172^\circ}{2} = \frac{204}{2} = 102^\circ$.

But if a pound of ice at 32° be mixed with a pound of water

at 172°, the temperature of the mixture will be still 32°, because the 140 degrees of caloric are absorbed in melting the ice: they have no effect on the thermometer, but exist in combination with the water as *latent* heat.

2. Bodies, in passing from the fluid to the æriform state, absorb heat. A vessel, containing a few ounces of water, was exposed to such a heat, that it boiled in about four minutes; but it required half an hour wholly to evaporate. The same degree of heat flowed into it after, as it had done before it reached the boiling point; but it was neither sensible in the water, the vessel, or the vapour: it was of course absorbed as necessary to the vaporous form.

M. Biot, a very able philosopher in France, has actually succeeded in forming water from hydrogen and oxygen gas, by compression only, independently of the electric sparks to which we before referred. The compression, he says, by bringing the particles of the gases into intimate union, makes them throw out heat sufficient to set them on fire, and the product of the combustion is water. It is thought probable that the torrents of rain, which sometimes accompany thunder-storms, may arise from the sudden combustion of these gases, which combustion is supposed to be occasioned by lightning.

The aurora borealis in the higher regions of the atmosphere, and the ignis fatuus, near the surface of the earth, are probably formed of hydrogen-gas: in the former case, this gas by its levity occupies the superior strata of the air; in the latter, the gas is derived from decayed vegetables, or stagnant water, or the decomposition of coaly substances.

The atmosphere, when its temperature is sufficiently low, deprives the water of a certain portion of its caloric: crystallization then follows, and the water is changed from its fluid state into ice. In the first act of freezing, the crystals of water are uniformly joined at the angle of 60°. Fresh water freezes at the temperature of 32° of Fahrenheit; but before salt water will run into crystals, it must be cooled down four or five degrees lower.

By the expansion of water in freezing, rocks and trees are frequently split; and it has been calculated that a globule of water of an inch in diameter, expands, in freezing, with a force superior to the resistance of many tons weight.

Water becomes still more solid in the composition of mortar and other cements, than in ice, having parted with more of its caloric in those combinations, than it does in the act of freezing. It enters into the composition of many mineral bodies, and appears to be the cause of their transparency. Many stones lose their transparency by being deprived even of a part of their water of crystallization, or that which entered into their composition; and are thus rendered brittle, or even pulverulent. Alkaline and earthy salts undergo similar changes. If water be thrown on quick lime, it will be retained with such force that nothing less than an intense red heat will separate it. And alumina, it is said, when mixed with water, retains a tenth of its weight of that fluid at a heat which would melt iron. In the case of fresh calcined plaster of Paris, or Roman cement, mixed with a sufficient portion of water, the affinity of the plaster for the water, is so great, that in a few minutes, these pulverulent matters will be converted into solids.

Exp. Boil a few copper filings in concentrated sulphuric-acid, to which a small portion of nitric acid has been added; and when the copper is dissolved, the mixture is to be diluted with a little water, and then left where it may cool gradually. In a few hours, crystals of blue vitriol will be found at the bottom of the vessel, as hard as some minerals. See Parke's Chemistry.

We have shewn in the last chapter, that the Alkalies, the Earths, and the Metallic oxydes are strictly connected in their most important chemical character, viz. that displayed in relation to acids. This fact being established, and the constitution of the metallic oxydes being known, chemists might naturally, from analogical reasoning, have assumed, but without any data, that the others were of a similar nature, in other words,

that the alkalies and earths consisted of metallic bases, combined with oxygen. This analogy was extended to the earths. It was often asserted that they were metallic oxydes, and some attempts have occasionally been made, but without success, to reduce them to the metallic form. The same analogy does not appear to have been extended to the alkalies, because the peculiar properties of these being less like, than those of the earths, to the properties of the metallic oxydes; and because the composition of one of them, ammonia, having been established, was found to have no apparent relation to metallic matter, or to oxygen. Ammonia, as we have seen, had long been known to consist of nitrogen and hydrogen, which, perhaps, led chemists aside from the analogy they might have otherwise pursued, and the two fixed alkalies were supposed to be of similar constitution. It was conjectured that either nitrogen or hydrogen was the alkaline principle, which being united with some of the earths, formed the fixed alkalies.

By the recent discovery of the composition of the alkalies and earths, the original analogy has been established. Sir Humphry Davy submitted the two fixed alkalies to the action of the Voltaic battery, effected their decomposition, and demonstrated that they consist of metallic bases combined with oxygen. He soon extended his investigations to several of the earths, and succeeded in obtaining metallic bases from two, and imperfect indications of metallization from others: but Dr. Clarke of Cambridge has recently succeeded in reducing most of them, including silex, one of the most refractory, to the metallic state, by exposing it with inflammables to ignition in a highly condensed mixture of the constituents of water. Analogy led Sir Humphry Davy to suspect that ammonia might also contain oxygen, and he stated several experiments by which this seemed to be proved; but his conclusions have since been overturned by the investigations of other chemists, particularly of the younger Berthollet, and of Dr. Henry. The analogy between ammonia and the other alkalies seemed to be further established by its amalgamation with quicksilver:

hence it was inferred, that it must have a metallic base, which by uniting with oxygen, forms this alkali. The experiments of Thenard and Gay-Lussac, however, appear to establish a different doctrine; and we are compelled, for the present, to regard ammonia as an exception to the general principle, that bodies, capable of neutralizing acid properties, have metallic bases.

In farther treating on this important subject, we may observe, that Sir Humphry Davy was led to institute the experiments, to which we have alluded, with the express view of decomposing the fixed alkalies, by his previous discovery, that by the powers of Voltaism, the principles of bodies are separated, according to a certain law; some being attracted to one pole, and some to the other: and that the strength of these attracting forces are proportional to the energy of the opposite electricities in the Voltaic circuit, to the conducting power, and concentration of the substances submitted to their action.

One of the early successful experiments in decomposing potash, is thus described in the Phil. Trans. for the year 1808: A small piece of pure potash, which had been exposed for a few seconds to the atmosphere, so as to give a conducting power to the surface, was connected with the negative side of the battery, in a state of intense activity; and a platina wire communicating with the positive side, was brought in contact with the upper surface of the alkali. A vivid action soon took place: the potash began to fuse at both its points of electrization. There was a violent effervescence at the upper surface; at the lower or negative surface, there was no liberation of elastic fluid, but small globules having a high metallic lustre, and being precisely similar in visible characters to quicksilver, appeared: some of which burst with an explosion, and a bright flame, as soon as they were formed; and others remained, and were first merely tarnished, and finally covered by a white film, which formed on their surfaces. "These globules," said the philosopher, "numerous experiments soon shewed to be

the substance I was in search of, viz. a peculiar inflammable principle, the basis of potash." This fact was confirmed by numerous experiments made in different ways, and it was concluded that potash was compounded of about 84 parts of a metallic base, and 16 of oxygen. The metallic base was named *Potassium*.

Potassium at the temperature of 60° Fahrenheit, appears in the form of small globules, very like mercury; but at this temperature it is imperfectly fluid: at the temperature of 100° the globules will readily run into one another. At the temperature of 50°, it is soft and malleable; and at 32°, it becomes hard and brittle. It is not volatile, requiring a red heat nearly to convert it into vapour. It is a perfect conductor of electricity, and a very good one of caloric. In these properties it has the closest resemblance to metals, and might therefore be expected to be like them in their most chàracteristic property, that of density: so far from this, however, it is lighter than water, or even pure alcohol. Compared with water, the specific gravities are as 6 to 10. In the solid form, potassium is heavier, but still it swims in distilled naphtha.

The chemical relations of this metal are not less singular than its physical properties. It combines slowly with oxygen, and without flame, at all temperatures below that of its volatilization; but at this degree of temperature combustion takes place, the heat is intense, and the light white and vivid. When brought into contact with water, potassium decomposes it with great violence; an explosion is produced with flame, and potash is formed. Placed on ice, it instantly burns with a bright flame, melting the ice. So very powerful is the action of this substance on water, that it discovers, by the decomposition which it produces, the smallest quantity of water in other liquids, as in alcohol or ether.

If potassium be thrown into solutions of the mineral acids, it inflames and burns on the surface, and the compound of potash with the acid is formed. It also inflames in the acid gases. It combines with the simple inflammable substances.

When, for instance, it is brought into contact with phosphorus under exposure to the air, both bodies become fluid, and burn, and a phosphate of potash is formed. It readily combines with the other metals, and produces some curious results, into which we cannot enter.

The experiments of Sir Humphry Davy on soda, were equally successful with those on potash; and both being conducted on similar principles, it is not necessary, in this sketch, to go over the same ground. The proportions in which the metallic base and oxygen are combined in soda, are as about 78 of base to 22 of oxygen. The metallic base, called *sodium*, is more like silver than mercury: it is exceedingly malleable, and is softer than any of the common metallic substances, its specific gravity is to that of water as 9 to 10 nearly. It combines with oxygen slowly, and without any luminous appearance, at common temperatures: but when subjected to considerable heat, this combination becomes more rapid; but no light is emitted till it has acquired a temperature nearly equal to that of ignition. It produces a white flame in oxygen-gas, and sends forth bright sparks, occasioning a very beautiful appearance. When thrown upon water, it produces a violent effervescence, with a loud hissing noise; it combines with the oxygen of the water to form soda, which is dissolved, and its hydrogen is disengaged. It combines with the metals, and in the quantity of $\frac{1}{40}$th, it renders mercury a fixed solid of the colour of silver, and the combination is attended with a considerable degree of heat.

The experiments of Sir Humphry Davy and others on ammonia, would, even in the most abridged form, take up more space than we can allow to them. It will be sufficient therefore to observe, that though a compound of hydrogen and nitrogen, it has several properties in common with metallic bodies. Thus it combines with mercury, and renders that fluid metal solid; and when combined even in a very minute proportion, reduces the specific of the mercury from 13 to 3. This singular compound is considered by Thenard and Lus-

sac as a union of mercury with ammonia, and hydrogen derived from the decomposition of the moisture or water; the presence of which is absolutely necessary to the success of experiment; and this view of the subject is confirmed by the fact, that the ammoniacal amalgam is again resolved into ammonia and hydrogen, by mere exposure to heat, or by agitation in vessels from which oxygen is excluded. Were it allowable in the present state of our knowledge to generalize, we might be tempted to infer that hydrogen, which appears to act an important part in the formation of the ammoniacal amalgam, may, by its combination with the other alkalies, form what we now consider as their metallic bases.

The decomposing effects of the Voltaic battery, naturally led Sir H. Davy to consider the principle of chemical attraction, which he refers to the negative and positive agencies of electricity. He found the neutral state of a variety of bodies such as to warrant this conclusion. Zinc, for instance, he ascertained to be naturally in a positive state, and copper in a negative state; these brought together exhibit signs of attraction. The same holds with regard to oxalic acid and lime, the former being negative and the latter positive, hence also their union is clearly understood on the principles of attraction. From experiments, united with the most intent observations, he assumes that all acids are naturally negative; and alkalies, earths, and metals positive; and from the combination of these, result neutral salts.

If sulphate of soda, which is compounded of sulphuric acid and soda, and which in its compound state is a neutral salt, be brought within the circuit of the Galvanic battery, a decomposition will take place, the acid will be attracted to the positive, and the alkali to the negative wire.

On the same principle, the decomposition of water is explained: one of its constituents, the oxygen, being negative, is attracted to the positive side; and the hydrogen, the other constituent, being itself positive, is attracted to the negative side. The general law then, as far as it can at present be as-

certained, is this, that different chemical agents have such a relation to Voltaism, that being brought within its influence, some are attracted forcibly to the positive, others to the negative end of the Voltaic batteries: the simple body, oxygen, and those compounds in which it predominates, particularly the acids, being attracted to the positive side; while inflammable substances, metals, and the compounds in which they appear to have the predominating power, as the alkalies, earths, and metallic oxydes, are attracted to the negative side. Or in other words, Voltaism and Electricity being identical, certain substances, as oxygen and the acids, are attracted by positively electrified surfaces, and repelled by those that are negatively electrified: while inflammable bodies, metals, metallic oxydes, the alkalies and the earths, are attracted by negatively electrified surfaces, and repelled by those which are positively excited. In consequence of this law, if the compound of oxygen and an inflammable base, as one of the fixed alkalies, be subjected to the action of the Voltaic battery, Plate IV. fig. 7, the oxygen is attracted to the positive end, and the inflammable base to the negative. A very able abridged account of Sir Humphry Davy's discoveries will be found in Mr. now Dr. Murray's Supplement to the first edition of his Chemistry.

Exp. 1. Having gently breathed on the surface of a very small piece of potash, place it on an insulated plate, connected with the negative side of a powerful Voltaic battery; when in a state of powerful activity, then bring the metallic wire from the positive side of the battery, to the upper surface of the alkali, and a vivid action will instantly take place. Very small globules of potassium will be disengaged, some of which will explode with a bright flame almost at the instant of formation.

2. Take some of the potassium thus formed, and heat it in a small glass vessel of oxygen-gas. A rapid combustion will take place, exhibiting a brilliant white flame, and the metallic globules will be converted into pure potash.

3. To acquire some idea of the specific gravity of potassium, place a few globules in a dry wine-glass, and pour upon them some alcohol, ether, or naphtha; when they will be seen ascending to the surface of the fluid, being lighter than the lightest liquid substances yet known.

4. If a small portion of potassium be dropped into a jar of oxymuriatic acid gas, it burns spontaneously, and emits a bright red light. The substance formed, in this experiment, is a true muriate of potash.

5. If a globule of potassium be dropped in water: it decomposes it with great violence: a bright flame is produced, and a solution of potash is the result of the experiment. If a similar globule be placed on ice, it burns with a brilliant flame, and perforates a hole in the solid, which likewise contains a solution of potash.

6. If a globule of sodium is thrown into hot water, the decomposition of the water is so violent, that small particles of the metal are thrown out of the water in a state of inflammation.

Since these brilliant discoveries, the attention of the chemical world has been attracted by the accidental discovery in France of a new substance, which is by some regarded as a simple body; but by others as an unknown base united to oxygen. This substance has obtained the name of *Iodine*. It is procured by the following process:—

Evaporate an aqueous solution of kelp till all the crystallizable salts are separated, and the new substance will remain in the *ley* or *mother water*. Evaporate this ley to dryness, and put the residue in a retort, with sulphuric acid; expose it to a gentle heat, to expel any remains of muriatic acid, and add black oxyde of manganese; a gentle heat will disengage a beautiful violet-coloured gas, which condenses in crystals, with metallic brilliancy like plumbago. This is the new substance, the properties of which have been examined by Clement and Desormes, Gay-Lussac, Sir H. Davy, and other eminent chemists. It melts at 158°, and volatilizes be-

low the temperature of boiling water. Its specific gravity is 4. It combines with metals; and forms with mercury, iron, tin, lead, and zinc, fusible compounds. These compounds, when put in water, are decomposed, and evolve metallic oxydes. It combines by heat with potassium, into a white matter, from which sulphuric acid sets the new substance again at liberty. It also combines with soda and the earths. When dissolved in a solution of caustic potash, it forms an explosive compound, resembling in its properties oxymuriate of potash: it also forms a detonating compound with ammonia. Oxygen has no action on it. When it is mixt with water, and a current of sulphuretted hydrogen is passed through it, an acid is formed, which unites with the various salsifiable bases; but it has not been yet obtained in the anhydrous state, except in combination with other acids. When the compound with phosphoric acid is sprinkled with water, an acid gas is set at liberty, which is a compound of iodic acid with water. From iodic acid united to water, the new substance may be again formed, by the addition of black oxyde of manganese, of nitric, or oxymuriatic acids. The new substance is acted on by sulphur and phosphorus, and forms compounds possessed of peculiar properties. Our limits do not admit of a more particular account of this interesting substance; but we must refer our readers to the original papers in the Philosophical Transactions, and the volumes of Thomson's Annals of Philosophy. Philosophers are divided respecting the nature of this new substance: Davy considers it as a simple body, and endeavours to shew its analogy to oxygen and oxymuriatic acid, which he regards as simple; while Berzelius and others look upon it as an hyperoxyde of a peculiar base, or as a hyperoxyde of iodine.

The works in chemistry, of established authority, are so numerous, that it is difficult to make a selection: we shall, therefore, refer to but very few; these will, however, amply elucidate its early principles, and from them the reader will

find abundance of references to writers on every branch of the subject. For the use of the uninitiated, the following will be found sufficient: indeed, any one of them will, of itself, be a good introduction, or guide, to the theory and practice of scientific chemistry.

"Dialogues in Chemistry," in two vols. 18mo. Price 7s. by the author of the "Scientific Dialogues."

"Conversations on Chemistry, by a Lady," 2 vols. 12mo. Price 14s.

"The Chemical Catechism. By Samuel Parkes," 1 vol. 8vo. Price 12s. Of which there is an abridgment, by the author, in a small volume entitled, "Rudiments of Chemistry, &c." Price 5s.

Of the larger works; adapted to those who have made some progress in the science, we may mention, and recommend to general notice,

"An Epitome of Chemistry, by William Henry;" which, from a very small volume, has grown to two large and closely printed octavos, illustrated with numerous plates.

"A System of Chemistry," in 5 vols. 8vo. by Thomas Thomson, M. D. The object of the author of this work has been to facilitate the progress of the science, by collecting into one body the numerous facts, which lay scattered through a multiplicity of writings, by blending with them the history of their gradual development, and by accompanying the whole with exact references to the original works, in which the discoveries have been registered.

"A System of Chemistry, by J. Murray," in 4 vols. 8vo. To which there is added a very valuable Supplement, containing a view of the recent discoveries in the science. The leading feature of this system, is the attention shewn to the general doctrines of chemistry, which the author has reviewed and illustrated in as ample a manner as possible, under the conviction, that the most important object to which the attention of those undertaking its study can be directed, is that relating to the principles by which its individual facts are con-

nected and arranged, because, without an intimate knowledge of these, the science is not acquired; and the acquisition of such knowledge, at once facilitates, and renders more interesting the prosecution of its minute details and applications. Also,

"Elements of Chemistry, by J. Murray," in 2 vols. 8vo. 3d edition, which contain a very able and luminous statement of the general doctrines of the science, and forms one of the best introductions to Chemistry ever given to the public.

"Chemistry applied to the Arts, by M. T. A. Chaptal," in 4 vols. 8vo. a very useful and entertaining work.

On a smaller scale is "A System of theoretical and practical Chemistry," in 2 vols. by Frederic Accum. In these volumes, the author assumes that the reader is unacquainted with the science, and has accordingly been very minute in his directions for the repetition of experiments.

"Elements of Chemistry, &c." by M. Lavoisier, translated into English by Mr. Kerr. Notwithstanding the various improvements and important discoveries which have been made since the death of the illustrious author of these Elements, his work will afford much satisfaction to every person who makes this science his pursuit.

CHAP. VIII.

NATURAL HISTORY.

Natural History—Method of Classification—The three kingdoms of nature. MINERALOGY connected with Chemistry—Different systems, viz. that of Pott—Gmelin—Cronstedt—Werner—Brochant—Hauy—Brongniart—Rome de Lisle. Explanation of Werner's method—Authors: Jameson—Kirwan—Hauy—Brochant—Klaproth—Aikin. GEOLOGY—Plutonic and Neptunian Theories. Bakewell.

NATURAL HISTORY, taken in its most extensive sense, signifies a knowledge and description of the whole universe, and of the several parts of which it is composed. According to this definition, the science is as extensive as nature itself; but in a more appropriate and limited sense, and to this we must necessarily confine ourselves, it treats of those substances of which the earth is composed, and of those organized bodies, whether vegetable or animal, which adorn its surface, soar into the air, or dwell in the bosom of the waters. In this restricted sense, natural history may be divided into two heads: the first teaches us the characteristics, or distinctive marks of each individual object, whether mineral, vegetable, or animal; the second renders us acquainted with all its peculiarities, in respect to its habits, its qualities, and its uses. To facilitate the attainment of the first, it is necessary to

adopt some system of classification, in which the individuals, that correspond in particular points, may be arranged together: hence, in the artificial system of Linnæus, and other writers on the subject, we have *species, genera, orders, classes,* and *kingdoms.*

The grand division of natural objects commonly adopted, is into three kingdoms, the *mineral, vegetable,* and *animal* kingdoms, because it is thought to be perfectly consistent with nature, and because, at first sight, some writers have thought it so clear and distinct, as to be almost impossible to make a mistake in referring any particular object to its proper kingdom. This arises from their having noticed only such objects as bear evident marks of the division to which they belong; but on more accurate observation, it will be found, that there are not only individuals, whose real characteristics it is difficult to ascertain, but that there is likewise one whole class of productions, called *zoophytes* by naturalists, which seem, indeed, to form the connecting link between the different kingdoms. "They are animals of the polypus kind, mostly covered with a calcareous crust, differing little in composition from the shells of lobsters, shrimps, and other shell-fish, and formed like them from an exudation, or secretion, on the surface of their bodies. These polypi are connected together by thousands, or even millions, and assume a great variety of appearances according to their arrangement: the same species, however, always assuming the same, or very nearly the same appearance. Some are connected together in form of a stem and branches, as the flustræ, sertulariæ, corallines and others; many of which have their offspring in the egg-state attached to them, and so situated as to bear an exact resemblance to the seed-vessels of plants. These are altogether so like to many of the sea-plants, as to be generally confounded with them, under the title of sea-weeds; but the attentive naturalist may, by examining them in their natural state, perceive the tentacula or feelers of each polypus extended in its search for food, and hastily retracting within its shell upon the least alarm. Many

of this description are found attached to oysters or other shell-fish; and often to stones and pebbles, which are covered, or occasionally wetted by the sea.

"Other zoophytes assume less regular figures, and are much more firm and solid, resembling the productions of the mineral kingdom. Madrepores and millepores, called often brainstones, are of this kind. At first sight they look very like stones and pebbles, or like pieces of chalk or marble; but on an accurate inspection, any one may perceive marks of an organic structure; and when they are in a recent state, may detect the inhabitants of their numerous cells."

Of the three grand divisions of nature, the animal kingdom stands highest in the scale; then the vegetable; and, lastly, the mineral kingdom. We shall begin with the lowest, and ascend to the highest; and we may observe, that minerals differ from vegetables and animals, in being produced fortuitously, growing by external secretion, and being only capable of destruction by mechanical or chemical force; while the other two are produced by generation, grow by nutrition, and are destroyed by death. While animals and vegetables thus agree in their general characters, they also possess features of marked distinction; but they both agree in an origin by generation, growth by nutrition, and a termination by death. In an organized structure, and an internal living principle, they differ in the power with which the living principle is endowed, and the effects that it is capable of exerting. In vegetables it is limited, as far as we know, to the properties of mere irritability and contractility: in the animal it superadds to these properties those of muscularity, sensation, and voluntary motion.

Mineralogy is that science which teaches us the properties of mineral bodies; and by which we learn to characterize, distinguish, and class them into a proper order. It seems to have been in a manner coeval with the world. Precious stones of various kinds appear to have been known and valued among the Jews and Egyptians in the time of Moses, and the most rude and barbarous nations seem to have had some

knowledge of the ores of different metals. Mineralogy, as a science, is connected with chemistry, and must advance with that to perfection. The practical mineralogist will not content himself with classing the substances connected with his study, merely by inspecting the outward appearance; but will dive deeper, by decomposing them according to the rules of chemistry. This method was carried a considerable way towards perfection, by M. J. H. Pott, a celebrated German chemist; whose works, "De Sulphuribus Metallorum," and "Observationes circa Sal," published about the middle of the last century, were very highly esteemed. Pott arranged earthy minerals according to their proportions of ingredients; but his four great classes, are the Alkaline, Siliceous, Argillaceous and Gypseous. An early death prevented this philosopher from extending his inquiries to the metals.

Cronstedt, the Swedish mineralogist, who was some years posterior to Pott, greatly improved upon his method. The system of Cronstedt was published in 1758, and for twenty years was generally received by the scientific world. In 1780, a translation of Crondstedt's mineral system appeared in Germany, accompanied with notes, by Werner, the Professor of Mineralogy, at Freyberg, in Saxony. Six years before, the professor had published a separate treatise on the classification of minerals, in which he exhibited much skill in a method of describing them by means of external characters. Cronstedt divided all mineral substances into four classes, viz. Terræ, Salia, Phlogistica, and Metalla. One of the most striking excellencies of Crondstedt's system, is the strict adherence to a fixed principle as the basis of classification; it is throughout chemical; and the principles on which the orders and genera are founded, are still much followed by chemical mineralogists. The compound rocks and petrifactions, which had been included in the mineral system of Linnæus and others, were by Cronstedt described in an appendix.

The system of Linnæus, just alluded to, was first published in 1736, and in an improved edition in 1768; but this is

rarely referred to, especially since Gmelin's system has been given to the world, which was founded, and must be regarded as an improvement, upon it. According to the system of Gmelin, minerals are divided into the five following classes:

I. Earths, which include the following orders:—Talcose—Ponderous—Calcareous—Argillaceous—Siliceous, and Adamantine.

II. Salts. III. Inflammable substances. IV. Metals. V. Petrifactions, divided into the *Animal* and Vegetable orders. As an introduction to Gmelin's Mineral Kingdom, which makes the seventh volume of Dr. Turton's translation of the Systema Naturæ, there is an account of all the Mineralogical Systems, from Bromel, in 1730, to that of Babington, in 1796; to which we refer our readers for information on the subject. Of some of the more important we shall, in this place, give the following brief account.

Werner's method is chiefly, if not wholly, followed in Germany, and is highly regarded in this and other countries. This system was introduced here by Mr. Kirwan, in 1784, who further elucidated it some years afterwards, by a new and much enlarged edition of the work. In preparing the latter edition, Mr. Kirwan had the advantage of consulting one of the completest and best arranged collections of minerals which had been made in any country. This was collected by Leskc, and after him, is called the Leskcian collection. It was arranged between the years 1782—1787, according to the principles of Werner, and with his assistance. After the death of Leskc, a catalogue of it was drawn up, which is divided into five parts: the first which is denominated the characteristic part, consists of specimens intended for the illustration of the external characters of the classification. The second, which is the systematic or oryctognostic part, comprehends all simple minerals distributed according to their genera and species, agreeably to the method at that time followed by Werner. The next is the geognostic or geological part, which includes the substances found in the different kinds of rocks,

as they are divided into primitive, transition, stratiform, alluvial, and volcanic mountains. This part of the collection is very rich in petrifactions. The fourth part is intended to illustrate the mineralogy of every country on the globe, by exhibiting its mineral productions. The fifth part is called the economical collection, and is formed of specimens which are employed in the arts and manufactures, as in architecture, sculpture, agriculture, jewelry, dying, clothing, pottery, glazing, enamelling, polishing of metals, furnace-building, medicine, metallurgy, &c. This short account of a very valuable collection may be a guide to collectors in the science. In France, the mineralogical treatises of Brochant, Hauy, and Brongniart may be noticed. The system of Brochant is formed on the principles of Werner's classification, and is thought to be one of the most perspicuous account of the German mineralogy that has yet been published. The system of Hauy divides itself into four classes. The first class consists of substances which are composed of an acid united to an earth and alkali, and sometimes to both. The second class includes only earthy substances, but sometimes combined with an alkali: it constitutes the siliceous genus of other systems. The third class comprehends combustible substances which are not metals. The metals form the fourth class. This is divided into three orders, which are characterized by their different degrees of oxydation. Besides these classes, there are three appendices. The first contains those substances, the nature of which is not sufficiently known to have their places accurately assigned in the system. The second appendix includes aggregates of different mineral substances; and the third is devoted to the consideration of volcanic products.

This system has the great merit of attending more perfectly than any other to the figure of crystals, by the measurement of their angles, and deducing all the varieties from the primitive form. It also contains a most ingenious theory of crystallization, by which every known fact may be explained without violating probability; while it enables the

mineralogist to distinguish the different species of crystallized bodies with singular accuracy. Its principal defect is in the number of important minerals, which, on account of their want of crystalline form, it refers to an appendix.

The system of Brongniart includes substances which are not treated of by writers on mineralogy, and is divided into five classes. The first contains those substances, excluding the metals, which are combined with oxygen; it contains two orders: the first including air and water, and the second the acids. The second class treats of saline bodies, and comprehends the alkaline and the earthy salts. The third class, containing stones, includes the hard, the magnesian, and the argillaceous stones. The fourth class contains the combustible substances, viz. the compound and simple. The fifth class includes metals, which are separated into the brittle and the ductile.

We must also notice the system of the celebrated Romé d'Lisle, who published an excellent work on crystallization, in 1783. In it, minerals are divided into three classes: the first contains saline crystals; the second stony crystals; and the third, metallic and semi-metallic crystals. He was the first who particularly directed the attention of mineralogists to the primitive form of crystals, of which he enumerates the following species.—1. Tetraedron. 2. Cube. 3. Octaedron. 4. Parallelopiped. 5. Rhomboidal octaedron, and 6. Dodecaedron, with triangular planes. He considered all minerals that agreed in crystallization, hardness, and specific gravity, as belonging to the same species.

His descriptions of the species were the most accurate and complete that had been delivered, and contributed more to the advancement of oryctognosie, than the writings of all preceding mineralogists.

The system of Werner, as given by Professor Jameson, is arranged according to the characters of minerals under four divisions: the external, the internal or chemical, the physical, and the empirical. To the first belong the characters drawn

from those properties which are obvious to the senses, such as colour, lustre, transparency, form, texture, hardness, and specific gravity; to the second, those which are derived from the chemical composition, or discovered by any chemical change which the mineral suffers; to the third are referred those characters which are afforded by certain physical properties, as electricity or magnetism; and to the fourth, a few characters derived from circumstances frequently observed with regard to a mineral, as the place where it is found, or the mineral by which it is usually accompanied.

Of these divisions, the external characters are considered as the most important, and it is chiefly with regard to them that so much labour has been employed on the language of mineralogy. The first property is *colour*, which, though but seldom highly characteristic, is one of the most obvious characters. It varies frequently in the same species, and is liable to change by very trivial foreign circumstances; it always enters, however, into the description. To give precise ideas of the different shades of colour, Werner has fixed on certain principal or standard colours, to which the subordinate shades are referred; defining them by means of an epithet, either expressive of the intermixture of one of the principal colours with the other, or derived from some substance familiarly known, the colour of which is constant. The principal characters are white, grey, black, blue, green, yellow, red, and brown. Of these are numerous subordinate colours, as blueish-grey, greyish black, &c. These are not always well marked, but incline to, are intermediate, or pass into each other. The shade of colour is of different intensities, as dark, deep, light, and pale. Besides these, other varieties are introduced, as dotted, striped, zoned, &c.; and the colour is varied by scraping the surface, affording a character called a streak.

Lustre denotes the relation which a fossil bears to the reflexion of the light from its surface. According to Werner, *resplendent* denotes the highest degree of lustre, which is such as to be seen at a considerable distance; *shining* is applied

when the lustre, though perceived at a distance, is not so well observed as on a near approach; *glistening*, when it is perceptible only at a very short distance; *glimmering*, when some of the minute parts only of a surface reflect a weak light; and *dull*, when lustre is entirely wanting. Different kinds of lustre are also marked, as the metallic, adamantine, vitreous, waxy, pearly, and resinous.

Transparency is denoted by different degrees and terms: *transparent* is applied where objects can be distinctly perceived through the interposed substance; *semi-transparent*, where objects are seen, but not distinctly, and this only through thin pieces; *translucent*, when light is in some measure transmitted, but objects cannot be observed; *opaque*, when no perceptible light is transmitted; connected with transparency is refraction, which, in the greater number of minerals, is single, but in some double, the latter giving a double image when an object is examined through them.

Form, the most important, perhaps, of the external characters, includes the figures of their crystals, and the various particular shapes which many of them, even in their uncrystallized state, often assume. The texture of fossils, as discovered by their fracture, affords another and very important discriminating character. The *fracture* may either present a surface continuous or uninterrupted; or it may present a surface composed of an aggregation of distinct parts, by which the continuity is more or less broken. The former is denominated the compact, the latter has been termed the jointed fracture: and each is subdivided into a number of varieties. Minerals are likewise discriminated by their hardness. The degree of it in a fossil is judged of with most certainty by the comparative facility or difficulty of impressing it. Four degrees of it are marked by Werner; the *hard*, in which the substance is not capable of being scratched by the knife, but gives sparks when struck by the steel; *semi-hard*, when it does not strike fire with steel, and may be scraped by the knife; *soft*, when it may be easily scraped with the knife, but

receives no impression from the nail; and *very soft*, when it is scratched by the nail.

Hauy determines the degrees of hardness according as one fossil impresses another. In one division, those are placed which scratch quartz; the individuals belonging to this are arranged as much as possible in the order of their relative hardness, so that when placed in a column, each will impress those beneath it. The second class are those which will scratch glass: these are arranged in a similar manner. In a third, those which scratch calcareous spar: and in a fourth, those which make no impression upon it.

Tenacity is that property which relates to the cohesion of the integrant particles of solid minerals; which, existing in different degrees, gives rise to the distinctions of brittle, malleable, and the intermediate degree of sectile.

The *frangibility* denotes the facility with which a mineral may be broken. It exists in different degrees, which are marked by the common terms of difficultly frangible, easily frangible, &c. According to the Wernerian system, the specific gravity is thus described; a mineral is said to be *supernatant*, which is lighter than water, and will swim upon its surface: it is called *light*, when the specific gravity is between 1. 0 and 2. 0: *rather heavy*, when the specific gravity is between 2. 0 and 4. 0: *heavy*, where it varies from 4. 0 to 6. 0: and *very heavy*, when the specific gravity is above 6. 0. To these external characters are added others of less importance, which are derived from properties peculiar to a few minerals, such as that of adhering to the tongue, soiling the finger, feeling hard or unctuous, giving a particular streak on paper, giving when struck a peculiar sound, feeling cold when applied to the tongue, having taste, or emitting some perceptible odour.

With respect to the chemical characters, *fusibility* is generally determined by the action of the blow-pipe; as we can thus operate on a small fragment, and perceive easily the appearances presented on fusion. Some minerals are perfectly

infusible by it; others melt with facility: some fuse with intumescence; others decrepitate or exfoliate when urged by the flame, or lose their colour: in some the fusion is partial; sometimes the result is a kind of scoria; in many cases it is a complete vitreous globule, transparent or opaque, and of various colours. These appearances are diversified, by adding to the substances various fluxes, as borax, and the phosphates of soda ammonia. The action of acids affords another chemical character of fossils, by observing whether they effervesce when touched with the acid; or whether, when a small fragment is immersed in it, it is partially or entirely dissolved: if the solution is fluid or gelatinous; and what appearances it presents from the action of re-agents. Diluted nitric acid is generally used in these trials. To the characters taken from certain physical properties are referred the phosphorescence, electricity, and magnetism of minerals. Phosphorescence is peculiar to some minerals, and is therefore a property well adapted to assist in their discrimination. In some it is excited by attrition, more or less strong; in others, by exposing them to heat. The electrical state, either positive or negative, is excited in some minerals by friction, in others by heat; and iron, in many states of combination, is discovered by its magnetic power.

In referring to the principal works in the science of mineralogy, we should direct the English reader's attention particularly to the "System of Mineralogy" by Robert Jameson, second edition, to whose introduction we have been in part indebted for the foregoing observations. This work consists of three volumes octavo, besides an additional "Treatise on the external Characters of Minerals." These volumes are devoted to the illustration of the mineral system. Each genus is fully described, beginning with the external characters, including the specific gravity as given, frequently, by several mineralogists:—then the constituent parts and chemical characters according to the most accurate analyses made as well on the

continent, as in this country:—then follow the physical characters, the Geognostic and Geographic situation: after which are described the uses to which the mineral is applied, and the methods adopted to render them best adapted to use. These volumes therefore contain a full illustration of the Oryctognostic system of Werner. Another volume is devoted to the science of Geognosy; but of this one, the second edition has not yet appeared. It contains a statement of the best ascertained facts respecting the aspect of the surface, and the structure of the crust of the earth.

To the volumes of Jameson, we shall add the titles of other works, to which Mr. Jameson has referred, with much applause, and which will obtain a place in the library of every Mineralogical student:

"Cristallographie, ou Description des Formes Propres à tous les Corps du Regne Minéral, par M. de Romé de Lisle." 4 tom. 1783.

"Elements of Mineralogy, by Richard Kirwan, Esq. 1794 and 1796." 2 vols. 8vo.

"Traité de Minéralogie, par l'Abbé Hauy." 4 tom. 1801.

"Traité Elémentaire de Minéralogie suivant les Principes du Professeur Werner, Conseiller des Mines de Saxe, par J. A. Brochant." 2 tom. 1803.

"Traité Elémentaire de Minéralogie, par Alexander Brognìart." 2 vols. 1816.

"Outlines of Mineralogy, by J. Kid, M. D." 2 vols. 8vo. 1809.

Klaproth's "Analytical Essays," &c.; and his "Mémoires de Chimie, contenant des Analyses des Minéraux, traduit de l'Allemand, par B. M. Tassert," in 2 vols. are excellent works.

In our own language, the work last published on the subject, and particularly adapted to persons entering upon the science, is:

"A Manual of Mineralogy, by Mr. Arthur Aikin," which includes the substance of some Lectures delivered before the members of the Geological Society of London. The author

of this small volume says, the first object of the mineralogical student is, or ought to be, the acquisition of a facility in identifying every mineral substance that presents itself to his notice; and he observes, that the characters of minerals are taken either from those properties that are immediately obvious to the senses—or from those which require for their manifestation the assistance of apparatus and re-agents, for the most part very simple and easy of application. Most of these have been already described; but Mr. Aikin's observations on what he calls the last set of characters, or those derived from the use of the blow-pipe, are well deserving the notice of the practical mineralogist.

Mr. Aikin says, that the Wernerian arrangement, with all its excellence, is by no means calculated for the use of a learner, so situated as to be obliged to depend on books and his own industry, with such specimens as he can himself procure from the rocks in his vicinity: and with regard to some modern systematic authors, he says, it should be borne in mind, that they are also teachers of mineralogy, and simply furnished with specimens and all other aids: most of the first mineralogists of Europe have proceeded from their schools; they have had ample practical proof of the efficacy of their mode of instruction, and would naturally therefore be led to discourage, or at least to take no pains in facilitating, the progress of the solitary student, who, whatever be his abilities, and whatever be his industry, must long feel his inferiority to one who has been educated in a regular school of the science, enjoying the advantage not only of books, but of living instructors: of well furnished cabinets, and of that encouragement and emulation which can only be duly excited, in scientific as well as in other pursuits, by the support of companions and the opposition of rivals.

" Under these circumstances it becomes very desirable that some new attempt should be made to construct an arrangement, whether natural or artificial is of little consequence, which by enabling the unassisted student to identify species,

may thus introduce him to the published systems, at least of those eminent professors to whose works and instructions the science is so deeply indebted."

Mr. Aikin's synopsis of the mineral kingdom is divided into four Classes, as follow:

Class I. Includes Non-Metallic combustible Minerals, which are divided into those that are combustible *with* and *without* flame.

II. Native Metals and Metalliferous minerals, which are divided into two orders: (1.) Those that are volatilizable wholly, or in part, by the blow-pipe, on charcoal, into a vapour which condenses in a pulverulent form on a piece of charcoal held over it. (2.) Those that are fixed and not volatilizable, except at a white heat.

III. Earthy minerals are divided into three orders: the *first* includes those that are soluble, either wholly or in considerable proportion, in cold, and moderately dilute muriatic acid: the *second*, the fusible before the blow-pipe: the *third*, those that are infusible before the blow-pipe.

IV. Saline minerals, included in two orders: viz. (1.) Those, which, when dissolved in water, afford a precipitate with carbonated alkali. (2.) Those that do not afford a precipitate with carbonated alkali.

We must not put an end to this chapter, without observing that mineralogy, which we have made a leading division in natural history, has sometimes been regarded as a mere branch of *Geology:* by such, the science of geology is considered as that branch of natural philosophy, which treats of the structure of the earth, in regard to its origin, composition, and the decomposition of its solid contents. Since, however, the time of Werner, Mineralogy has been generally made to include Geology; and to prevent confusion, the word *Geognosy* has, by some persons, been invented to supply its place: but Professor Jameson, who has devoted a volume to Geognosy, admits that the word Geology, is of a more extensive signification; "for the word λογος," he says, "comprehends the whole

science or rationale of any subject, and, therefore, Geognosy is only a branch of Geology." "The object of Geology is to unfold the structure of the globe, to discover by what causes its parts have been arranged; from what operations have originated the general stratification of its materials, the inequalities with which its surface is diversified, and the immense number of different substances of which it is composed."*

Without entering much into the subject, we may briefly touch on the leading controversy which exists with regard to this science. It is generally admitted, that the shell of the globe has, at some period, been in a state of fluidity, whence it has taken its present arrangement. The only two causes regarded as competent to such an effect, are the operations of fire, or some solvent: it is then a question of much difficulty to ascertain by which of these means this effect has been produced. If a solvent has been the cause, that solvent must have been water, for there is no other fluid in nature in sufficient abundance, to have acted the part of a solvent upon so large a scale.

Hence two distinct theories arise, founded upon these questions: Is the present structure of the solid contents of the earth, so far as it is capable of examination, the result of igneous fusion, or of aqueous solution? Is the Plutonic or the Neptunian system founded on the stronger basis?—The Plutonic theory was first started in modern times by M. Buffon, but its defenders are now chiefly confined to our own country; and consist of Dr. Hutton, Professor Playfair, and Sir James Hall, who are powerfully opposed by the equally respectable authorities of Werner, Saussure, and Kirwan; and it may be added, that the general opinion is much in favour of the Neptunian theory, or that entertained by the last named philosophers. These theories have been discussed in the notes to Mr. Jameson's third volume, to which we have already referred; and have been more completely investigated

* Comparative View of the Huttonian and Neptunian Systems.

in an admirable work entitled, "A Comparative View of the Huttonian and Neptunian Systems of Geology," understood to be the production of Dr. John Murray, of Edinburgh.

In addition to the works noticed as strictly mineralogical, the following is well deserving the student's attention: "An Introduction to Geology, illustrative of the general Structure of the Earth, comprising the Elements of the Science, &c. by Robert Bakewell." According to this author, the knowledge of the structure, composition, and arrangement of the materials, which form mountains, rocks, or strata, constitutes the *first* part of geology. In the *second* part is included the direction, structure, and extent of the mineral dykes and metallic veins by which they are intersected. The changes which are taking place on the surface of the globe by the agency of inundations, earthquakes, and volcanoes, make the *third* part. And the *fourth* part, or speculative geology, is chiefly confined to an investigation of the causes, that have probably operated in the formation of rocks and mountains, and also those by which the revolutions in the earth's surface have been subsequently affected. Mr. Bakewell's work is illustrated with plates, and he has devoted a long chapter to the Geology of England, which he concludes by observing, that "there are few extensive estates, whose value would not be greatly increased by a correct knowledge of the mineral substances that they contain. The well known maxim of Lord Bacon, that *knowledge is power*, is particularly applicable to this subject; for as Sir John Sinclair has justly stated, "a knowledge of our subterranean wealth, would be the means of furnishing greater sources of opulence to the country, than the acquisition of the mines of Mexico or Peru."

CHAP. IX.

NATURAL HISTORY,

Continued.

BOTANY. Parts of a plant described—Root—Body, viz. Trunk—Leaves—Fulcra—Buds. Flowers—Fructification—Calyx—Corolla—Stamina—Pistilla—Pericarpium—Capsula—Semina—Receptaculum. Classification of plants—Systems—Classes, Orders, Genera and Species—Linnæus's artificial System—Classes and Orders—Jussieu's natural System.

BOTANY is that branch of natural history, which relates to what is called the vegetable kingdom, the second of the three grand assemblages into which all terrestrial objects are divided. As a science, it is not confined to the description and classification of plants, but comprehends many other important particulars, some of which are the following.

I. The description, or nomenclature of the several parts of a plant which are externally visible. Every plant is composed of several parts, which differ from each other in their outward appearance: many of these are themselves compound, and obviously capable of being divided into subordinate parts. The first great division, adopted by most botanists, is into the root, the body of the plant, and the fructification.

The *root*, according to Linnæus, consists of the *radicle* and the *descending caudex*. The radicle is that fibrous part which draws nourishment from the earth, and in many plants constitutes the whole root. The descending caudex is properly part of the stock, or body of the plant, which extends itself below the surface of the ground, as the ascending caudex rises above it.

Roots are divided, according to the term of their duration, into annual, biennial, and perennial. The *annual, biennial,* and *perennial:* the two former produce flowers and fruits only once, and then soon die, the annual pass through all the stages of vegetable life in one season: the biennial throw out leaves the first year, but do not complete the fructification till the next. The perennial root has within itself a principle of continued life, and gives being to new flowers and seeds, year after year, for a considerable length of time.

The *body* of the plant springs from the root, and is terminated by the fructification: it consists of the trunk, the leaves, the fulcra, props or supports, and the hybernacula or buds.

The *trunk* bears both leaves and flowers, as the trunks and branches of all trees and shrubs, as well as of many herbaceous plants. By its means the organs of plants are raised to a fit height above the ground, and presented in various directions to the atmosphere and light. In germination, it always takes a contrary direction to the root. As it advances in growth, it is either able to support itself, or it twines round, or adheres to other bodies. The trunk or stem is variously formed in different plants, but our limits do not allow us to enter into particulars.

The *leaves* are not absolutely necessary to all plants, for on some occasions the stems perform the function of the leaves. They are generally so formed as to present a large surface to the atmosphere; when they are of any other hue than green, they are said to be coloured. Their duration is for the most part annual, but in some trees and shrubs they

survive two or more seasons, and such plants being always in leaf are denominated ever-greens.

Leaves have a natural tendency to present their upper surface to the light, and turn that surface towards it in whatever direction it is presented to them. When trees in leaf are nailed to a wall, and the position of their leaves is consequently disturbed, they soon recover their natural direction. Light evidently acts as a wholesome stimulus to their upper surfaces, and as a hurtful one to the under. When the latter is forcibly presented for a long period to its rays, destruction is the consequence. Leaves seem to require occasional repose from the action of light on their upper surface; for, when it is withdrawn from them, many leaves close or fold themselves together, as if in a state of relaxation, and spread themselves forth again at the returning beams of the morning. This is more especially the case with winged leaves, as those of the pea kind. Those of the white acacia, robinia pseudoacacia, have been remarked by Bonnet, to be over-excited by the sun of a very hot day, and to fold their upper sides together, in a manner directly contrary to their nocturnal posture. The effect of moisture upon leaves, every one must have observed. By absorption from the atmosphere, they are refreshed; and by evaporation, especially when separated from their stalks, they soon fade and wither. Aquatic vegetables, whose leaves are immersed in the water, both absorb and perspire with peculiar facility. Anatomical investigations have shewn that the nutritious juices, imbibed from the earth, and become sap, are carried by appropriate vessels into the substance of the leaves. Knight, in his papers in the Philosophical Transactions, has demonstrated that these juices are returned from each leaf, not into the wood, but into the bark. Hence the theory of vegetation has been established. It appears that the sap is carried into the leaves for the purpose of being acted upon by air and light, with the assistance of heat and moisture. By all these agents a most material change is wrought in its component parts and qualities, differing widely according to the

diversity of the species. Thus the resinous, oily, mucilaginous, saccharine, bitter, acid, or alkaline secretions, are elaborated. The heedless observer of a leaf is little aware of the wonderful operations constantly going on in its delicate substance; nor can the most enlightened philosopher explain more than a very small part of the chemical processes of which it is the immediate agent. It is scarcely necessary to observe how materially plants differ in the flavour and qualities of their leaves, all which must depend in a great measure on the operation of the leaf itself; for the common sap of plants, from which all their secretions are made, differs very little in plants, whose qualities are very unlike to each other those qualities depending upon the secreted fluids elaborated principally by the leaves.

Leaves are subject to a sort of disease, by which they become partially spotted or streaked with white or yellow. In this state they are termed variegated, and occasionally contribute to the ornament of our gardens. The whiteness frequently extends to the leaf-stalk, and sometimes to the branch, as may be seen in the variegated elder. Such varieties are propagated by cuttings, layers, or roots, but not by seed. They appear to be somewhat more tender than the plant in its natural state. One variety of the holly has, in addition to a yellow variegation, a beautiful tinge of purple; but this is a rare instance. In the amaranthus tri-color, the leaves are naturally adorned with most beautiful and splendid colours; and in some other species of the same genus, with more uniform and less vivid tints.

The irritable nature of some leaves is remarkable, not but that all leaves may truly be said to possess irritability with respect to light. The phenomena, however, to which we now allude, are of the most striking kind. The sensitive plant, mimosa-pudica, common in hot-houses, when touched by any extraneous body, folds up its leaves one after another, while their foot-stalks droop as if dying. After a while they recover themselves again. Each leaf of the dionœa musci-

pula, or Venus's fly-trap, is furnished with a pair of toothed lobes, which, when touched near the base, fold themselves together, and imprison any insect that may be in their way. It is presumed that the air evolved by the body of the dead insect, may be wholesome to the plant; for leaves are known to purify air impregnated with carbonic acid gas, produced from the breathing of animals, or the burning of a candle. The sarracenia, of which several species from America are now cultivated in many of our gardens, bears tubular leaves, which retain water in their hollows, and imprison insects, whose putrefying bodies evidently produce a quantity of bad air; and analogy leads us to suppose that the air is destined to be serviceable to the constitution of the vegetable. See Dr. Smith's Introduction.

There are various appendages to the herbage of plants, all of which are comprehended by Linnæus under the term *fulcra*, *props*, or supports; which term, in its literal signification, applies to very few of them: they may be thus enumerated in short. *Stipula*, a leafy appendage to the true leaves, or to their stalks, for the most part in pairs, more or less constant even in the same genus or species: in roses they are invariable; in willows very much the contrary. *Bractea;* this is a leafy appendage to the flower or stalk, very conspicuous in the lime-tree. *Spina*, a thorn, proceeds from the wood itself, as in the wild pear-tree, which loses its thorns by cultivation. *Aculeus*, a prickle, proceeds from the bark only, having no connexion whatever with the wood, as in the rose and bramble. Prickles are not effaced by culture. *Cirrus*, a tendril, is intended as a support for weak stems, by which they are enabled to climb rocks, or the trunks of lofty trees. Thus vines, passion-flowers, and vetches, are elevated to a considerable height above the ground. *Glandula*, is a small tumour secreting a sweet, resinous, and sometimes fragrant liquor; as on the calyx of the moss-rose, the foot-stalks of passion-flowers, and the leaf of the salix pentandria; which last being pressed between paper, leaves the impression of an elegant

row of yellow dots. *Pilus*, a hair, which includes all the various kinds of pubescence; bristles, wool, &c., many of which are curious objects for the microscope. Some of these bristles discharge a poison, as in the nettle, causing a great irritation, whenever they are touched in such a manner as for their points to wound the skin.

Buds have a great analogy to the bulbs and knobs of the roots of herbaceous plants. In these the vital principle is latent till a proper season for its evolution. For this reason, buds are essential to the trees and shrubs of cold countries, and are formed in the course of the summer in the bosom of their leaves. In most cases they are guarded by scales furnished with gum, or a woolliness, as an additional defence. Plants are propagated by buds as readily as by roots. Those of one tree may be engrafted on the bark of another of the same species, by which means many valuable varieties are multiplied.

The various modes in which *flowers* are situated upon, or connected with a plant, are of great botanical importance, not only for specific distinctions, but as leading to a knowledge of natural families or orders. In the Linnæan system, they do not enter into the generic characters of plants; these are founded on the seven parts of fructification, which will be shortly described. The following is a brief account of the several kinds of efflorescence.

Verticillus, a *whorl*, in which the flowers surround the stem, in a garland or ring; such is the flower of the dead nettle, lamium, &c. *Racemus*, a cluster, bears several flowers, each on its own stalk, loosely ranged along one common stalk, like a bunch of currants. *Spica*, is composed of numerous crowded flowers along an upright common stalk, of which wheat and barley afford good examples. Spicula is a term applied only to the grasses. *Corymbus* is a flat topped spike, the long stalks of whose lower flowers raise them to a level with the uppermost, or nearly so; this is exemplified in the cabbage and wall-flower. *Fasciculus*, a close bundle of

flowers, on little stalks, level at the top, as in the sweet-william. *Capitulum*, a head or tuft, is composed of numerous flowers, collected in a globular form, as the thrift. *Umbella* consists of several stalks called rays, spreading from a common centre, like an umbrella; examples of this may be seen in the parsley, carrot, and hemlock. *Cyma* consists of stalks springing from a common centre, but which are afterwards irregularly subdivided, as in the laurustinus and alder. *Panicula* is a loose subdivided bunch of flowers arranged without order, as in the oat. *Thyrsus*, a bunch, is a very dense panicle, as, according to Linnæus, the lilac and butter-burr, and Dr. Smith adds to these a bunch of grapes.

Under the term *fructification*, are comprehended not only all the parts of the fruit, but also those of the flower. The parts of fructification are seven, four of which are indispensable to the production of new individuals, viz. the stamen, the pistil, the seed, and the receptacle: the other three, the calyx, corolla, and the pericarp, are often wanting, and, therefore, do not appear essential to fructification.

1. The *calyx*, or flower cup, or external covering of the flower. Of these there are seven kinds. (1.) The *perianthium*, or calyx, properly so called, when it is contiguous to, and makes part of the flower, as the five green leaves which encompass the rose. (2.) The *involucrum*, which is remote from the flower, as in the umbeliferous tribe. (3.) The *amentum*, a catkin, formed of numerous scales, attached to the receptacle, and falling off with it: in catkins, which bear seed, the scales are often enlarged into a cone, as in the fir. (4.) *Spatha*, a sheath, is remote from the flower, as in the snow-drop. (5.) *Gluma*, a husk, to which belongs the arista or awn, which is not constant in the same species of grass or corn. A very elegant feathery awn is seen in the stipa pennata, feather-grass. (6.) *Perichætium*, a scaly sheath, investing the fruit-stalk in some mosses, as the hypnum. (7.) *Volva*, the wrapper of the fungus tribe, which shelters the fructifica-

tion, as in mushrooms, or investing the base of their stalk, as in many fungi.

2. *Corolla,* the generally coloured leaves of a flower, always situated within the calyx; when both are present, this term comprehends both the *petal,* and the *nectary.* A flower consists of *one* petal, denominated monopetalous; or of many, called polypetalous. Monopetalous flowers are either campanulate, funnel-shaped, salver-shaped, wheel-shaped, ringent, like the mouth of an animal, or personate, closed by a palate. The petal consists of a tube and limb. Polypetalous flowers are either cruciform, as in the common wall-flower; rosaceous; papilionaceous, as in the pea; or incomplete, when some parts are wanting. The parts of polypetalous flowers, are the claw and the border. According to the systems of Botanists, neither the calyx nor corolla is indispensably necessary to a flower. Both are wanting in the hippuris, and one or other is deficient in many genera. The nectary is frequently a part of, or an appendage to the corolla; sometimes the petal itself secretes honey, sometimes a set of glands performs this function; and in other cases, there is a peculiar petal-like apparatus for preparing and preserving the nectarious juice. The peculiar use of the honey is to attract insects to promote the impregnation of the flower.

3. *Stamina,* or stamens, are situated within the corolla, and are various in number, in different flowers, from one to several hundreds. These are the essential organs of impregnation. A stamen usually consists of the *filament* and *anther,* the latter of these only is essential. Its most common shape is oblong, composed of two cells, which burst by a longitudinal fissure on the outside. The cells of the anther are destined to contain the pollen or dust, which appears to the naked eye like a very fine powder: but when examined by means of a microscope, it is frequently found to have a very peculiar structure in different plants. It is mostly discharged in dry and sunny weather; or it adheres to the rough bodies of in-

sects, as they frequent the flowers in search of honey. Each grain of pollen continues entire, so long as it is dry; being a little membranous bag, so constructed as to burst when it meets with moisture, discharging a fine elastic vapour, which is the effective part of the pollen. The stamina are liable to be obliterated when the plant increases much by the root, they are then metamorphosed into petals, in what are called double flowers.

4. *Pistilla.* The pistils are also essential parts of a flower, usually standing within the circle formed by the stamens, in the very centre of it, but sometimes they are placed in a different individual in the same species. That furnished with stamens being called the male, or barren blossom;—that with pistils the female, or fertile one. Each pistil consists of three parts, the *germen*, or rudiments of the future fruit or seed: the *style*, which is not universal; and the *stigma*, which is the part destined to receive the pollen, and being furnished with its own appropriate moisture, to make that substance explode. By this means the seeds within the germen are rendered fertile. Pistils, as well as stamens, are occasionally obliterated or changed into petals.

5. The *pericarpium*, or seed-vessel, is formed of the germen enlarged, and is not an essential part; for many plants have naked seeds, guarded only by the permanent parts of the flower. Some seed-vessels remain closed while they are moist, and split open with a considerable elastic force when ripe and dry: some serve for the food of animals, by whose means they are transported to a distance: others make their way into the ground, by some peculiar apparatus near the spot where they are produced, while others are wafted by the winds, or transported by the waters, to far distant situations. There are several kinds of seed-vessels with different names, as,

(1.) The *capsule*, exemplified in the datura, or thorn-apple. (2.) The *siliqua*, which is of two kinds: these are exemplified in radishes, wall-flowers, &c. and also in honesty, shepherd's-purse, and candy-tuft. (3.) *Legume*, is the fruit of the pea,

and other butterfly shaped flowers, as the lupine, broom, &c. (4.) The *drupa* is a stone-fruit, like the peach and cherry. (5.) *Pomum,* an apple, contains a capsule of several cells in a fleshy coat. (6.) *Bacca,* a berry, containing one or more seeds lodged in a pulp, as the gooseberry and currant. Some berries are compound, as the raspberry; others are spurious, the pulp originating from some part not properly belonging to the fruit, as the calyx in the mulberry, and the receptacle in the strawberry: and (7.) The *Strobilus,* a cone, originates from a catkin, becomes hardened, and is enlarged into a compound seed-vessel, as in the fir, birch, &c.

6. *Semina,* the seeds, are the most essential parts of fructification, being those to which all the others are subservient. The seeds are composed of several parts, of which the most important is the *embryo,* or germ; Linnæus calls it *corculum,* a little heart, in allusion to its shape in the walnut; in which, and also in the bean, and other leguminous plants, it is readily observed. It is generally lodged within the substance of the seed, except in grasses. The cotyledons, or seed-lobes, are intimately connected with the embryo, and are two in number; but in the fir genus they are more numerous. When the seed has sent its root into the ground, these organs generally rise above the surface, and perform the functions of leaves till the proper foliage is produced.

Seeds are often accompanied by certain appendages or accessory parts, of which the chief are as follows: (1.) *Pappus,* the seed-down, is the feathery or bristly crown of several seeds that have no seed vessel, as in the dandelion, thistle, &c. (2.) *Cauda,* a tail, is an elongated appendage to seeds, originating from the permanent style. It is generally feathery, as in the clematis, or virgin's bower. (3.) *Ala,* a wing, is a dilated membranous appendage, serving to waft seeds along in the air. To these may be added various spines, hooks, scales, and crests, serving in many cases to attach such seeds as are furnished with them, to the rough coats of animals, and so to promote their dispersion.

7. *Receptaculum*, the receptacle, is the common base or point of connexion of the parts of fructification; and must exist in all cases, in some form or other. It comes chiefly into notice when it assumes any particular form, as in compound flowers, the dandelion, daisy, and thistle. The receptacle of the seeds is a term used for the part to which they are attached in a seed-vessel.

Classification of Plants. In endeavouring to class plants, a number of systems have been invented by learned men of different countries. The resemblances or affinities of plants have been thought sufficient to enable botanists to arrange them by their external characters, and this arrangement has been called a *natural* system. Others have founded their systems on the number, proportion, and relation of minute, and not very obvious parts, and this arrangement has been denominated an *artificial* system; and others have selected the sexual characters, and founded their system on the number and variety of such organs. This is the sexual system.

Every system in Natural History contains certain divisions and subdivisions, which are denominated *class, order, genus, species,* and *variety.* When a particular character is found to be common to many plants, such plants constitute a *class.* In the system of Tournefort, the petals; in that of Ray, the *fruit;* and in that of Linnæus, the stamina, furnish classic artificial characters.

Should some of the plants in one class, independently of the particular character, agree in some others of an inferior description, they create an *order.* The orders in Tournefort's system are founded on the fruit; those in Linnæus, on the number of styles, or female organs. A particular enumeration of the latter is subjoined, a little farther on, to the respective classes. It will be seen that the names of the orders, as well as those of the classes, are of Greek origin, and significative of the character of the orders to which they are applied. The names of these orders are often the same in different classes, because the same idea predominates in their institution.

If a few plants, possessing the double characters of class

and order, are found also to exhibit, among themselves, some common distinctive marks, they create a *genus*. Each of the plants in a genus is named a *species;* and a *variety* is a species differing from the rest, in colour, size, or some accidental circumstances. A *genus* then, is an assemblage of several species; that is, of plants that resemble one another in their most essential parts; and has been compared to a family, all the members of which bear the same surname, though each individual is distinguished by a particular specific name. An *order* includes many genera, and a *class* several orders.

We shall not pretend to enumerate all the botanical systems that have been invented, and that have at various periods been popular, and had many adherents. The two systems, that at present divide the botanical world between them, are the artificial one of Linnæus, and the natural one of Jussieu. These, according to Dr. Smith, are not rivals, but allies and mutual supports. Plants are so numerous, and those parts upon which all systems depend, so liable to variations and irregularities, that neither the Linnæan system, nor any other artificial system can conform to them all with sufficient precision to be in any degree infallible. Again, every natural system is necessarily so incomplete for want of a perfect knowledge of all the plants in the world, and of their mutual dependencies on each other, as well as of the best possible manner of defining and characterizing the classes and orders in which human contrivance is obliged to dispose them. But the two methods used in conjunction eminently assist each other. If a new plant cannot be made out by artificial marks, its affinity may be guessed at in the natural system.

The Linnæan system is founded, as we have observed, on the number, situation, and proportion of the essential organs of impregnation, termed stamens and pistils. There are twenty-four classes, which chiefly owe their distinctions to the stamina: the orders are generally marked by the number of pistils, or by some other circumstance equally intelligible. The following table gives the name of the classes, and of the several orders which are included in each class.

Classes.		Orders.
1. Monandria	including	Monogynia—Digynia.
2. Diandria	———	Monogynia—Digynia—Trigynia.
3. Triandria	———	Monogynia—Digynia—Trigynia.
4. Tetrandia	———	Monogynia—Digynia—Trigynia—Tetragynia
5. Pentandria	———	Monogynia—Digynia—Trigynia—Tetragynia—Pentagynia—Decagynia—Polygynia.
6. Hexandria	———	Monogynia—Digynia—Trigynia—Tetragynia—Polygynia.
7. Heptandria	———	Monogynia—Digynia—Tetragynia—Heptagynia.
8. Octandria	———	Monogynia—Digynia—Trigynia—Tetragynia.
9. Enneandria	———	Monogynia—Trigynia—Hexagynia.
10. Decandria	———	Monogynia—Digynia—Trigynia—Pentagynia.
11. Dodecandria	———	Monogynia—Digynia—Trigynia—Tetragynia—Pentagynia—Dodecagynia.
12. Icosandria	———	Monogynia—Digynia—Pentagynia—Polygynia.
13. Polyandria	———	Monogynia—Digynia—Trigynia—Tetragynia—Pentagynia—Hexagynia—Polygynia.
14. Didynamia	———	Gymnospermia—Angiospermia.
15. Tetradynamia	———	Siliculoso—Siliquosa.
16. Monadelphia	———	Triandria—Pentandria—Heptandria—Octandria — Decandria — Endecandria — Dodecandria—Polyandria.
17. Diadelphia	———	Pentandria—Hexandria—Octandria—Decandria.
18. Polyadelphia	———	Pentandria—Icosandria—Polyandria.
19. Syngenesia	———	Polygamia æqualis—Polygamia superflua—Polygamia frustanea—Polygamia necessaria—Polygamia segregata.
20. Gynandria	———	Diandria—Triandria—Hexandria—Dodecandria.
21. Monoecia	———	Monandria—Diandria—Triandria—Tetrandria—Pentandria—Hexandria—Polyandria.

22. Dioecia	including	Monandria--Diandria--Triandria--Tetrandria — Pentandria—Hexandria—Octandria — Enneandria—Decandria—Dodecandria—Isocandria—Polyandria—Monadelphia—Gynandria.
23. Polygamia	———	Monoecia—Dioecia—Trioecia.
24. Cryptogamia	———	Filices—Musci—Hepaticæ—Algæ—Fungi.

The magnificent natural order of palms was placed by Linnæus as an appendix to this sexual system, because their parts of fructification were then not well known; but they are now, so completely understood, that the plants are easily reducible to the regular classes of the Linnæan system. Palms have been denominated the princes of the vegetable kingdom, and are remarkable for their lofty growth, and their simple stems, crowned with ever-green leaves and abundant fruits. Among them are the date and cocoa-nut. Some supply whole nations with oil for food, or economical uses, from their fruits: with wine from the juices of their stems, or with cordage from its fibres.

The classes respectively refer to the number of the stamens, or male parts, as far as class 13, inclusively, and afterwards to their position. The orders are denominated from the number of the pistils, or female parts, as far as to class 13, inclusively; and afterwards from some other circumstance of a different description, selected to constitute an ordinal character, such as gymnospermic, or with naked seeds; angiospermic, or with seeds in a pericarp: siliculous, or with seeds in a pod. Sometimes, and very frequently, the order is derived from the number of the males, male parts, or anthers; the class embracing such orders, being denominated from their position, peculiar junction with, or disjunction from the females. And sometimes it is denominated from other characteristics of a class, where the class in question is marked by a characteristic of a different kind. Thus the term polygamia, which constitutes class 23, serves, with various trivial and additional names, for several orders under class 19,

or syngenesia; while again, the terms monoecia and dioecia, which designate classes 21, 22, are adopted to represent distinct orders in class 23. It is hence obvious, not only that the sexual system of Linnæus is partly natural and partly artificial, and as such imperfect in its arrangement; but that the artificial section of it is by no means totally free from intricacy and confusion. For an admirable illustration of the classes and orders we refer our readers to the article Botany, in Nicholson's British Encyclopedia.

We may farther observe, that though Linnæus was the author of the foregoing artificial arrangement, yet at one time his inclination appears to have been divided between a system purely natural, and one in which an artificial arrangement might be allowed to unite. He accordingly introduced a natural system, consisting of fifty-eight natural orders, which have since been much simplified, and may be reduced to the following eight alone.

1. Fungi, or Funguses, distinguished from other vegetables by the peculiarity of their form, which is commonly fleshy, coriaceous, or woody.

2. Algæ or flags, which approach more nearly to the generality of vegetables, but have the leaf, stem, and fructification united; sometimes exhibiting the appearance of fibres, and sometimes resembling the fret-work of architecture.

3. Musci, or Mosses, evincing for the most part the common external appearance of vegetables, but varying in their fruit and flowers.

4. Filices, or Ferns, vegetables that never push from the root more than one leaf on a foot-stalk, (some Indian species excepted), and whose leaf, at its evolution, is generally rolled up in a spiral.

5. Gramina, or Grasses, which have long and slender leaves, with a straw for a stem, commonly jointed, and bearing but one seed in each flower; which flower is also peculiar to this division.

6. Lilia, or Lilies, with bulbous or tuberous roots, long,

slender leaves, spatheous flowers, without calyx, or instead of calyx, a spathe.

7. Palmæ, or Palms, exhibiting an arboreous stem, but never branches. The leaves rise from the stem, which is called stipes. The flowers issue from a spathe.

8. Plantæ, or Plants, including every vegetable that does not arrange itself under the preceding divisions. They are, herbs, under-shrubs, shrubs, and trees.

Respecting the two last sub-divisions, it should be observed, that climate and culture have often a considerable influence over them, so that trees and shrubs often run into one another.

With respect to the natural system of arrangement of Jussieu, we may observe, that its primary divisions are founded upon the structure of the seed, whence is derived the distinction of all plants into Acotyledons, that is, those that are destitute of cotyledons: Monocotyledons, that is, such as have one cotyledon; and Dicotyledons, such as have two. Under the last are included a few genera that have numerous cotyledons, as the Pinus and its allies. The classes of Jussieu's method are fifteen, and comprize a hundred orders. These classes have no appropriate names, but are distinguished by numbers, with a short definition of the essential character. The orders, except those of the first class, are for the most part named after some principal genus belonging to each.

At the end of this system is a large assemblage of genera under the denomination of "Plantæ incertæ sedis," as not capable of being referred to any of the foregoing orders. This must be the case with all natural systems, unless it were possible for their contrivers to have all the genera of plants from every corner of the earth before them at one view. As long as any remain to be discovered, or any that are discovered, are imperfectly known, every such system must be defective. A natural system of botanical arrangement being therefore unattainable in perfection, Botanists in general resort, for daily

use, to artificial ones. When they meet with an unknown plant, they count its stamens and styles, or observe any other circumstance attending those organs, on which the characters of the Linnæan classes are founded. Having thus ascertained the class of the plant, they in like manner ascertain its order. They then proceed to compare the parts of its flower and fruit with the characters of each genus, in that order, till one be found that agrees with them. Having ascertained the genus, they look over the characters of the species, till they have met with the right. Hence are learnt the generic and specific name of the plant, and other circumstances and facts that are recorded of it. Such is the mode of applying the Linnæan system to use; but it may happen, that a plant is found, whose number of stamens is variable, or different from the usual number in the natural genus to which it evidently belongs. In this case, Linnæus has provided a remedy, by enumerating at the head of each class, all such anomalous species, as far as he could determine them, so that if the plant do not agree with any of the regular genera or the class, the botanists will seek it among the irregular species.

If after all their attempts, the plant cannot be arranged in the artificial system, then that of Jussieu may be resorted to. The true way to use this system, is to consider, to what known genus or family the plant most approaches in its habits and leading characters. By turning to such through the help of the index, and reading the characters of the corresponding order, it will be soon seen whether the right is obtained. At any rate this practice will be highly useful, in leading to the familiar acquaintance with the natural orders and affinities. When Botanists have determined the genus of a plant in Jussieu, as the species are not treated of in that system, they must still have recourse to the Linnæan system for that part of the subject.

" By such a manner of associating these two great authors, we render them truly serviceable to each other, and to the science; whereas, by placing them in opposition, we only make stumbling-blocks of all their defects; for there must be

defects in all attempts of the human intellect to keep pace with the infinite wisdom and variety displayed in the works of God." See an admirable introduction to *Botany*, under the word, in Nicholson's British Encyclopedia, from which we have borrowed very freely. The whole work in 6 vols. 8vo. will be found very deserving a place in the student's library. For the sake of learners, who have no assistance in this department of knowledge, the three following works, or any one of them, will be found adequate as guides to the science of Botany.

"An Introduction to Botany, by Priscilla Wakefield." 12mo.

"Letters on the Elements of Botany, addressed to a Lady, by J. J. Rousseau, translated by Thomas Martyn, Professor of Botany at the University of Cambridge." 8vo.

"Elements of the Science of Botany, established by Linnæus, with examples to illustrate the Classes and Orders of his System," two small volumes, with numerous plates.

A work of very superior merit on this subject is entitled, "An Introduction to Physiological and Systematical Botany, by Dr., now Sir James Smith, F. R. S. and President of the Linnæan Society."

In addition to these may be mentioned, for the English reader, the two volumes contained, in "Linnæus's General System of Nature, in the three Kingdoms of Animals, Vegetables, and Minerals," translated by Dr. Turton.

Wildenow's "Principles of Botany and of Vegetable Physiology:" 8vo. and

Pulteney's "General View of the Writings of Linnæus," 8vo.

To give a more comprehensive knowledge of the subject, we would recommend to the student of Botany.

The writings of Linnæus on this science, "Willdenow's Species Plantarum," and an excellent manual entitled, "Synopsis Plantarum seu Enchiridium Botanicum Curante, Dr. C. H. Persoon," 2 vols. 12mo. Paris, 1805.

CHAP. X.

NATURAL HISTORY,

Continued.

Natural History—Zoology—General arrangement—Linnæan system—Divisions of—Linnæan classes—Mammalia—Aves—Amphibia—Pisces—Insects—Vermes.

ZOOLOGY comprizes the whole animal world, or all those beings which are called by the name of Quadrupeds, Birds, Amphibia, Fishes, Insects, Testaceous animals, and Zoophytes. These latter, as we have shewn, chap viii, are of very different forms, and are allied by many resemblances to the vegetable world.

In taking a brief survey of the animal world, we shall begin with the highest order of animals, and descend to the lowest. It is not, in the present state of our knowledge, practicable to make out a continuous chain, or series of animals, united throughout by evidently connected links. It has indeed been observed, that all the productions of Nature, seem rather connected by many points of affinity, on different sides, than by a regular chain of gradation; so that the face of nature may be rather said to represent a reticulated or polygonal surface, than to be disposed in a continued linear progression. If, however, a perfectly natural chain or arrangement of animals cannot be contrived, it is still necessary to form some kind of

classification, in order to keep together such tribes as most evidently resemble each other. Hence Naturalists have invented several systems or distributions of animals, formed either from the general external appearance, or from the structure of their principal organs.

The most ancient division of animals is that of Aristotle, who divided them into *viviparous*, that is, those that produce living, and perfectly formed young, and into *oviparous*, or such as are produced from eggs. This kind of division continued to be in use with some modification, till towards the decline of the seventeenth century; when our countryman Mr. Ray, formed a new classification, founded chiefly on the structure and nature of the heart and lungs in the different tribes; and the Linnæan arrangement of the animal kingdom is, in fact, founded upon that of Ray, particularly with respect to quadrupeds.

The Linnæan system, which we shall briefly explain, with respect to the animal world, is thus distributed: 1. Into animals that have warm and red blood, and a heart divided into two cavities, or ventricles, as anatomists term them. These animals consist of quadrupeds and birds—the former being *viviparous*, the latter *oviparous*.

3. The next division consists of such animals as have a heart with a single ventricle, while the blood, though red, is of a far lower temperature than in quadrupeds and birds, so that it is commonly called cold blood. These animals consist of what are denominated by Linnæus, *Amphibia*, such are Tortoises, Frogs, Lizards, and Serpents; and also *Fishes*. The Amphibia, or the Frog, Tortoise, Lizard, and Serpent tribes, have, what Linnæus calls arbitrary lungs, or such as can suspend respiration at pleasure, for a considerable time, without injury to the animal. Fishes, instead of lungs, are furnished with gills, in which innumerable divisions of blood-vessels are disposed in semi-circular ranges.

3. The third division of animals consists of such as have a heart with a single cavity, and a cold whitish, or nearly co-

lourless blood. These animals consist of Insects, and of a very numerous and diversified tribe, called by the name of worms. The former of these, viz. the Insects, are distinguished by the particular organs called antennæ; which are jointed and moveable for the most part; while the latter, or worms, are characterized by having tentacula, or flexible feelers.

To proceed to the Linnæan arrangement. By this all animals are divided into six classes, of which, the characters are chiefly taken from the internal structure of the beings treated of. The six classes are as follow, viz. MAMMALIA, AVES, AMPHIBIA, PISCES, INSECTÆ, VERMES.

1. The class MAMMALIA, comprehends all such animals as suckle their young, being furnished with proper organs for the purpose. In all the animals of this class, the plan or fabric of the skeleton, as well as their internal organs, bears a degree of general resemblance to that of Man. Their *outward* covering consists in general, of hair; but in some few the animal matter of the hair takes the form of distinct spines or quills, as in the Porcupine and Hedge-hog tribe. In others, the same substance is expanded into the appearance of strong and broad scales, as in the genus Manis; and in others, as in the Armadillo, instead of hair, we meet with strong bony zones or bands, forming a regular suit of armour.

The instruments of loco-motion, or feet, in the Mammalia, are generally four in number, and furnished with separate toes, guarded by claws. In some, as in the monkey tribe, the feet have the appearance of hands: in some tribes the feet are shod with strong hoofs, either entire, or divided.

In such of the Mammalia as possess the power of flight, as in the Bat tribe, the fore-feet are drawn out into slender fingers of an immoderate length, and united by a common membrane or web. In some of the aquatic mammalia, as the Seals, both the fore and hind feet are very strongly or widely webbed; and in the Whale, there are in reality, only two feet, the bones of which are inclosed in what are commonly called

the fins, while the lobes of the tail answer the purpose of a pair of hind feet. The arms, or offensive and defensive weapons of the mammalia, besides the claws and teeth, are principally the horns; inserted in various directions, and on different parts, in different tribes. The horns are either perennial or annual. In the Rhinoceros, the horn is perennial, and situated on the top of the nose. In the Deer tribe, the horns are annual, branched, covered while young with a soft villous skin or coat; they grow from the tip, and become very solid and strong at their full size. In the Ox tribe, as well as in the Sheep and Goat, they are hollow, mounted on a bony core, and grow from the base.

The teeth in quadrupeds or mammalia, are of three kinds: 1. The front or cutting teeth are of a broad, compressed structure, designed for cutting food: 2. Sharp, lengthened, or canine teeth, situated on each side the cutting teeth, and calculated for tearing and dividing the food: and 3. Grinders, with broad, angular tops, for grinding the food. The teeth, as will be seen, afford a principal character in forming the orders and genera. In some the canine teeth are wanting; in others the front teeth; and some few are totally destitute of teeth.

The tail in quadrupeds is formed by a continuation of the vertebræ, or joints of the back-bone; and is in some of great length, and covered with very long hair: in others it is very short; and in some few entirely wanting, as in the Apes.

The senses of the mammalia consist, as in man, of the organs of sight, hearing, tasting, and smelling, and the power of feeling; and in many of these animals these organs are of greater acuteness than in man. The eyes, in some quadrupeds, as the horse, are furnished with what is called a nictating membrane, or semi-transparent guard, situated beneath the eye-lids, and which can at pleasure be drawn over the ball of the eye for its defence. The nose, or organ of smelling, is more or less compressed and lengthened. In the Elephant it is extended in a most wonderful manner into a long and tubular proboscis, or trunk, at the tip of which are placed the

nostrils. The teats or mammæ are found in these animals, and, as has been observed, give rise to the Linnæan title to the whole class.

The *first* class of animals, or MAMMALIA, is divided into seven *Orders*. 1. The first of these orders is denominated *Primates,* as containing the chiefs of the creation. Its characters are four front or cutting teeth, above and below, and one canine or sharpened tooth on each side of these. In a mere zoological view, the human kind stands at the head of this order, forming the Linnæan genus Homo. Next to this is the genus Simia, including Apes, Baboons, and Monkeys; the Oran Outang being the chief of the tribe. The other genera of the order Primates are the Lemur, or Macauco, and the Bat.

2. The second order, denominated *Bruta,* is characterized by a want of front or cutting teeth, in the upper and lower jaw. The feet are armed with strong claws: their pace is in general slow, and their food is principally vegetable. Of this order the chief genera are the Rhinoceros, the Elephant, the Bradypus or Sloth, the Myrmecophaga or Ant-eater, the Dasypus or Armadillo, and the Platypus or Ornithorynchus, or Duck-bill. The last, though placed among the mammalia, is a most extraordinary and dubious quadruped: it is not certain that it is possessed of any mammæ: it is a native of Australasia or New Holland, where it is found in fresh-water lakes, and is supposed to feed on worms, water insects, and various weeds, in the manner of a duck. It is obliged to rise occasionally to the surface of the water, in order to breathe.

3. The third order, called *Feræ,* contains, among other genera; the Phoca or Seal, the Canis or Dog, the Felis or Cat, Ursus the Bear, and Erinaceus the Hedge-hog. This order contains the predacious quadrupeds, all agreeing in having teeth evidently calculated for feeding on flesh. The front teeth, which are usually six above and below, approach to a conical or pointed figure; the canine teeth are long, and

the grinders not flattened at top. The claws of the feet are sharp, and more or less curved in the different species.

4. The fourth order is entitled *Glires*. The principal character of the animals of this order consists in a pair of very conspicuous, strong, and lengthened teeth, placed close together in the front of both jaws. They have no canine teeth, but are furnished with grinders on each side. This order comprehends Beavers, Mice, Squirrels, Hares, and other genera.

5. The fifth order, named *Pecora*, contains all the *Cattle*, commonly so called, as Oxen, Sheep, Goats, and others. It also comprises the Camelopardi, the Deer tribe, the Antelopes, the Musk, and a few others. The animals of this order have no fore-teeth in the upper jaw, but six or eight in the under jaw. They have four stomachs: they are hoofed, and the hoofs are divided in the middle; and excepting the camel, they have two false hoofs, which in walking do not touch the ground. Such as have horns, have no tusks; and such as have tusks, have no horns. Another characteristic belonging to most of this tribe of Mammalia, is the power of rumination, that is, of throwing up into the mouth at intervals, a portion of food which has been hastily swallowed during feeding, in order that it may undergo a more complete grinding by the teeth. The whole order Pecora, without a single exception, feeds entirely on vegetable food.

6. The sixth order is denominated *Belluæ*, and includes four genera only, viz. the Equus or horse, the Hippopotamus, the Sus or Hog, and the Tapür. The animals of this order have obtuse fore-teeth in each jaw: they have the peculiar property of breathing through the nostrils, and not through the mouth.

7. The seventh order is called *Cete*, of which the animals have pectoral fins instead of feet; the tail is horizontal, and flattened. They have many peculiarities. Being warm-blooded animals, and breathing air like quadrupeds, and yet destined

to live in the water, their nostrils are situated on the top of their heads; so that by rising to the surface of the water, they take in air, and expire, without raising their heads out of water. The fat, or blubber, as it is called, of these animals, is entirely lodged on the surface of their bodies under the skin, serving as a warm covering, and preserving their heat, which the constant application of cold water would otherwise soon dissipate. The genera are the Monodon, Balæna, Physeter, and Delphinus.

II. The *second* class of animals is denominated Aves, or birds; and the branch of science which considers and describes these animals, their natures and kinds, their forms, external and internal, and which teaches their economy and uses, is called Ornithology. Birds have been defined as two-footed animals, covered with feathers, and furnished with wings. Like the mammalia they have warm blood, a heart with two ventricles and two auricles, and lungs for the purpose of respiration. They are however distinguished from them by their feet, feathers, wings, and horny bill, as well as by the circumstance of the females laying eggs.

The feathers with which birds are covered, are analogous in their nature to the hair of quadrupeds. Beneath the common feathers or general plumage, the skin in birds is immediately covered with a much finer or softer feathery substance, called down. The external or common feathers, are called by different names, on different parts of the animal. The longest of the wing feathers, which are generally ten in number in each wing, are called the first or great quills, or the *remiges primores*, as being the chief oars or guiders. The feathers, constituting the middle part of the wing, are called *secondaries*, or second quills, and are more numerous than the first: the feathers descending along each side of the back, are called scapula feathers: the small feathers covering the shoulders are called smaller wing coverts; the next series to these are denominated the larger wing coverts, and at the edge of the shoulder are a few rather strong and slightly lengthened feathers, constituting

what is called the false or spurious wing. The tail, in most birds, consists of twelve feathers, in some there are only ten, and in others there are eighteen, twenty, and twenty-four. Sometimes on each side the tail, or above it, at the lower part of the back, are placed several long feathers of a different structure from the rest.

The eyes of birds are more or less convex in the different tribes, and in general it may be observed that the sense of sight is more acute in birds than in most other animals; and they seem to possess a greater degree of power in accommodating the convexity of the eye to any particular distance, than other animals. They have no outward ear, but the internal one is formed on the same general plan as in quadrupeds.

The bill in all birds consists of two mandibles, the upper and lower, the former is uniformly fixed, except in the genus of parrots, which have the power of moving the upper mandible to assist them in climbing. No birds have teeth, but some have serrated mandibles, the serræ, however, are not immersed in the sockets. There is a considerable difference in the form of their feet, according to their manner of life. Hence their feet have obtained various technical names, as they are fitted for perching, walking, running, swimming, or diving. For perching, those seem best adapted, which have three toes in the front part of the foot, and one backward; with the two outward toes partly connected by a membrane; among those that walk, this membrane is not to be found. Birds used to swimming, have their feet wholly palmated, or pinnated, or semi-palmated.

Birds are divided by Linnæus into six orders, viz. *Accipitres* or predacious birds; such as Vultures, Eagles, Hawks, Owls, &c. The general appearance of these birds of prey, bespeaks their character, and their mode of procuring sustenance. Their beaks are hooked, strong, and notched at the point; and the neck is strong and muscular, to enable them to strike their prey with force. Their legs are short and strong

and their talons sharp and crooked, to force down, and keep their prey on the ground, or grasp it in their claws, and soar away with it. Their sight is so piercing, that when so high as to be almost out of human sight, they can descry their prey upon the ground; and their flight is so rapid, that they can dart upon it with the celerity of a meteor.

2. *Picæ*, or pies, containing all the birds of the Crow and Jay kind, the Parrots, the Wood-peckers, the King-fishers, and many others. This order includes birds of very different habits. Some of them feed on grass, worms, and insects: some on fruit and berries: some on fish; and some on insects. The humming-bird extracts its food from flowers, with its forked tongue, and rooks are remarkably fond of grubs and beetles, particularly of the cock-chafer.

3. The third order, *Anseres*, comprehends all kinds of water-fowl. The webbed feet of these birds are admirably adapted to assist them in swimming; and the great quantity of oil secreted by the glands near the tail, and rubbed by means of their bills over all the feathers of their body, enables them to live on the water, without ever being very wet. The birds of this order live mostly on fish, and some have been trained to the catching of fish for the use of their masters. Most of the water-fowl are birds of passage with us, and leave the lakes of Sweden, Denmark and Lapland, where they breed in summer, to visit our warmer climate during the rigour of winter. They fly in large flocks, and always preserve a certain order during their flight.

4. The next order of birds is denominated *Grallæ* or *Waders*, consisting of all the Heron tribe, the Curlews, the Plovers, and other numerous tribes which have long legs, and frequent watery situations. Their bills are very long, and in many their necks are likewise of a remarkable length, to enable them to search in moist, boggy, and marshy places for the food which is best adapted to their nature. The heron is a great devourer of fish: the woodcock and snipe live wholly on insects, for the taking of which their bills are very

nicely adapted: the plovers live on worms. The Bustard, and some few others, live chiefly on herbs and grain.

5. The next order is denominated *Gallinæ*, or such as are more or less allied to the common domestic fowl; and consequently contains the Pheasant and Partridge tribe, the Peacock, Turkey, and a variety of other birds. The common cock and hen are supposed to have been originally transported from India, where they are still occasionally found in a state of nature. Though not found in America, when that continent was first explored by Europeans, the common fowl has, by his fecundity, already become as plentiful there as in Europe. America, in return for these, has given us the turkey, which is now domesticated all over Europe. The peacock is a native of India: the guinea-fowl, of Africa; and the Pheasant, though not domesticated, but living wild in our woods, is not originally a British bird.

6. *Passeres*, or the sparrow tribe, includes a vast variety of birds, which are generally small; and among them are all the songsters and warblers of our groves and thickets. The food of this order of birds is either berries, fruit, and occasionally grain; or insects, and the eggs and larvæ of insects.

III. The animals of the third CLASS of the animal kingdom called *Amphibia*, are very remarkable both for their singular external appearance, and internal conformation. They are oviparous, and differ from the viviparous quadrupeds, and also from birds, in the structure of the heart and lungs: they have the singular property of being able to suspend the function of respiration, and can perform it in a more arbitrary manner than other animals.

The characteristic of this class being a peculiarity of internal organization, it is not at all surprising that the animals which it comprehends, should agree more in certain propensities and habits, than in external appearance: accordingly it contains some that resemble fishes, as the shark and skate; and others that more nearly resemble quadrupeds, as the tortoise and crocodile; and some that in general appearance resemble

no other class of animals, as snakes and serpents; some of which can move with equal ease on land or in water, though they have neither feet nor fins. The points of agreement in the whole class are all the consequence of the above stated peculiarity in the organs of respiration. Besides, all amphibious animals have hearts with only one ventricle, which organization is necessarily connected with the peculiarity of their breathing: and they are all remarkably tenacious of life. Amphibia have no grinders, but most of them sharp pointed teeth, and their bodies are either naked or scaly. They are oviparous, some of them depositing hard eggs, or covered with a calcareous shell, as in birds, while others deposit soft eggs or spawn, either in the form of continued chains of eggs, or else in heaps or loose clusters. In several of the Amphibia, as in the Viper tribe, and in some Lizards, the eggs are hatched internally. The young of such as deposit hard or shelled eggs, are commonly produced in their perfect or complete form, differing from the parent animal in size alone: but the young of many of those which are produced from spawn or soft eggs, pass through a kind of tadpole state, as is the case with frogs, and appear for some time in a form very different from that which they afterwards assume.

The whole class was formerly divided by Linnæus into four orders, distinguished as follows.

1. *Reptiles*, which breathe through the mouth, and have four feet. This includes the families of the tortoise, lizard, and frog.

2. *Serpents*, which breathe through the mouth, but have neither legs, nor fins, nor ears; they change their place by an undulatory motion. Of this order there were six genera.

3 *Meantes*, having both gills and lungs. There is only one species in this order, namely, the Syren, a singular animal discovered in Carolina, inhabiting swampy and muddy situations, which is now placed among the reptiles.

4. *Nantes*, which breathe indifferently through their lungs and gills, and have fins. This order is most allied to fishes

properly so called, and it contains among others, the shark, lamprey, skate, and the several others, which are now classed among fishes. Hence the Class AMPHIBIA is now divided into two orders, viz. *Reptiles* and *Serpents*. Among the former, are the sea-tortoise or turtle; and the crocodile, being a species of the *Lizard* genus, so fierce and formidable to other animals. Its usual food is fish, but when that fails, it attacks any animal, and even man. It is found in the Nile, the Niger, and in the Ganges.

One of the most singular properties of Serpents, is that of casting their skins: and so completely is this operation performed, that even the external coats of the eyes themselves make a part of the cast skin.

IV. The fourth CLASS is denominated *fishes*, and the study of this branch of the science of Natural History is called *Icthyology*. The heart of fishes like that of Amphibia is unilocular, that is, it has but one chief cavity: their blood is of a less temperature than that of the higher order of animals, as quadrupeds and birds. Their organs of breathing, analogous to the lungs in quadrupeds, are distinguished by the name of gills; by means of which they probably derive support from the oxygen of air contained in the water, or have the means of decomposing the water, and thus exist by its oxygenous part; so that the same process of nature, which in the higher orders of animals takes place in the internal cavity of the lungs, is brought about in fishes externally by means of the subdivided branching of their gills.

Aristotle suggested the arrangement of fishes into the cetaceous, cartilaginous, and spinous orders. After him, another division obtained, which was founded upon the habitation of fishes, or those places in which they reside; and according to this classification, fishes were divided into those that dwell in the sea, lakes, and rivers. It was however soon found, that many fishes reside indiscriminately in all these situations, this method was therefore abandoned by Willoughby and Ray, who went back to the Aristotelian method; to which Linnæus added

further subdivisions. Soon after this restoration, it was discovered that the internal structure of cetaceous fishes, as whales, &c. was very much allied to the mammalia, or quadrupeds; and that, upon strict investigation, the external figure bore an equal coincidence. It was observed that they are destitute of gills, and breathe by means of lungs, and on that account are obliged to rise frequently to the surface of the water for respiration: that they also resemble land-animals in having warm blood, and in several other important circumstances, particularly that of suckling their young, and hence they were transferred to the class *mammalia*.

Another order of fishes, in which the gills differ in their structure from the rest, having an appearance somewhat approaching to hollow lungs, was placed among the amphibia, on the supposition that these, viz. cartilaginous fishes, possessed real lungs as well as gills.

A more particular and correct investigation has discovered that these supposed lungs are only a modification of gills, and they have accordingly been restored from the class amphibia to that of fishes; and we have now six orders under the class pisces or fishes: *four* derived from the fishes, whose muscles are supported by spines or bony matter, and denominated the *Apodal*, the *Thoracic*, the *Jugular*, and the *Abdominal*. This arrangement is founded on the absence of the ventral fin, as in the *apodes*; or on its situation with regard to the pectoral fins: and the other *two* are the *cartilaginous* fishes, subdivided into the *branchiostegous*, or those whose gills are destitute of bony rays; and the *chondropterygious* or those with cartilaginous gills.

1. The fish of the order *Apodes* are without ventral fins, as the eel, the conger, &c.

2. The order *Jugulares*, includes fish in which the ventral fins are placed before the pectoral, as in the cod-fish and blenny.

3. The *Thoracici*, in which the ventral fins are under the pectoral, as in the perch, mackarel, &c.

4. The *Abdominales,* in which the ventral fins are placed behind the pectoral, as in the salmon and pike.

5. The *Branchiostegous* order includes fishes that are destitute of bony rays, &c.

6. The *Chondropterygious* order, which consists of fishes which are destitute of bone altogether, and possessed of cartilage instead.

Such are the orders: the generic character is taken from the shape of the body, covering, structure, figure, and parts of the head, but chiefly from the branchiostegous membrane. The specific character is taken from the cirri, jaws, fins, spines, lateral line, digitated appendages, tail and colour.

It may be observed, before we quit this class of animals, that the general form and structure are finely adapted to the peculiarity of the element in which they live. Being themselves nearly of the same specific gravity as the water which they inhabit, their small fins are all that is requisite to enable them to move with ease, and steer their course with pleasure.

V. The fifth Class of animals in the Linnæan system, contains *Insects,* and the study of this branch of science is *Entomology.* The characters by which insects are distinguished from other animals are as follow. First, they are furnished with several feet, never fewer than six; and sometimes a great many, inasmuch that we have among them millipedes or creatures with so many feet, that they are designated as if they had a thousand. Secondly, the flesh, or muscular part of their frame, is affixed to the internal surface of their skin, which is generally of a tough, strong substance, and in many even hard or horny. Thirdly, they breathe, by a sort of spiracles, or breathing holes, situated at certain distances along each side of the body; and lastly, the head is commonly furnished with a peculiar pair of antennæ, or jointed horns, which are extremely various in the different tribes, and form a leading character in the institution of the genera.

The first state in which the generality of Insects appear, is that of an egg: from this is hatched the animal in its second state, in which it is often called a caterpillar, though its more general and appropriate name is that of *Larva*, being, as it were, the mask or disguise of the animal in its future form. The larva differs much in its appearance, according to the different genus to which it belongs. In the moth and butterfly tribe, it is emphatically called by the name of caterpillar. In the beetle tribe it is of a thick, heavy form, with the body of a rounded and bulging appearance at the hind-part. In the locust or grasshopper tribe, and some others of the same order, it does not differ from the complete insect, except in not being furnished with wings. In the fly and bee genera, and some others, it is popularly known by the name of maggot, of an oval form, without feet. In dragon flies, and in water-beetles, &c. it is often of a very singular form, and differs more from the complete insect than in any other, except those of the moth and butterfly tribe.

When the time arrives in which the Larva is to change into its next state, that of *Chrysalis*, or, as Linnæus calls it, *Pupa*, it ceases to feed; and then, surrounding itself with a covering, either formed of materials furnished by its own body, or of extraneous matter collected for the purpose, it appears in the form of a Pupa. The Pupa differs in different tribes of insects almost as much as the larva.

From the Pupa emerges, at length, the complete insect, in its perfect or ultimate form, from which it can never after change, nor can it receive any farther increase of growth. This last or perfect state of an insect is called the *Imago*.

The eyes in insects differ in the different tribes: the greater number of insects, however, are furnished apparently with two eyes, situated on each side the head. The outward coat of these eyes is composed of a prodigious number of minute hexagonal convexities, like so many convex lenses or glasses,

but the exact manner in which vision is performed by these organs is not exactly ascertained. The head of the common dragon-fly, or Libellula, is furnished, it is said, with no less than 25,000 of these diminutive lenses.

According to the Linnæan system of Entomology, there are seven orders of insects, classed according to the number and substance of their wings, or from their being altogether without wings.

1. The first order is named *Coleoptera*, or insects with crustaceous wings. These have four wings; the upper ones, acting as cases or coverings to the true wings, are called elytra, and are of a hard horny substance. The true wings, which when the animal is in a state of rest, are under the elytra, are membranaceous, and more delicate than the finest gauze. When the animal is preparing for flight, the elytra are raised, and the membranaceous wings are unfolded, and spread out to the air. This order includes all kinds of beetles, of which there are said to be above a thousand different species in this country.

2. The *Hemiptera*, or insects with half-wing cases, are those that are included in the second order. Though the elytra of these are only half as long as the body, they are quite sufficient for covering the true wings, when the animal is at rest, to which they prove a shield and defence. The elytra of this order of insects, are not only shorter, but softer than those of the coleopterous order, being more like parchment than horn.

3. The third order is denominated *Lepidoptera*, that is, the butterfly-tribe. The insects of this order have four membranaceous wings, covered with scales, arranged nearly like the tiles upon a house. This order includes all kinds of moths, as well as butterflies, their wings being similar, though their antennæ and general habits differ. The wings of this tribe, some of which display great beauty and variety of shade and colouring, have been frequently the subject of micro-

scopical investigation. See Dialogues on the Microscope, 2 vols. 18mo.

4. The fourth order, *Neuroptera*, includes insects with naked membranaceous or nerved wings, and without stings. The insects of this order differ from those of the last in their wings being without the minute scales or down: dragon-flies, ephemera, and others, belong to this order.

5. The next order is denominated *Hymenoptera*, or insects with four naked membranaceous wings, which are distinguished from the Neuroptera, by their having stings. It includes wasps, bees, ants, and others. The sting is in some genera within the body, except when in the act of using: in others it is always without the abdomen, and enclosed in a cylindrical sheath.

6. The sixth order includes insects with two wings, and it is on that account denominated Diptera. To this order belong all the fly tribe, with gnats, gad-flies, &c. They all have two poisers or balancers, instead of under-wings, being little balls at the summit of pedicles which are attached to the abdomen.

7. The last order is denominated *Aptera*, or insects without wings. This order includes all insects that are destitute of wings in both sexes. It is well known that there are several insects, as the female glow-worm, the neuters of ants, the female coccus, and some others, which, though wingless themselves, are furnished with wings in the other sex or sexes. These, however, are not ranged with the order aptera, but to such orders as their winged mates belong. The apterous order comprehends also the different species of lice, fleas, mites, and spiders; likewise lobsters, crabs, shrimps, and prawns.

VI. The last CLASS of the animal kingdom, according to the Linnæan system, is denominated *Vermes*, or *worms*, and includes a great variety of animals. It is not only arranged the last in order, but the creatures which it contains, when compared with those of the other classes, seem to be the least

perfect, possessing neither eyes, nor ears, nor heads, nor feet. Many of them, as the corals, and sponges, approach very near to vegetables; and others, as the madrepores and shell-fish, resemble, in their coverings at least, certain productions of the mineral kingdom. All, however, may, no doubt, be considered as perfectly complete both in structure and endowments for the stations which they are designed to hold, and for the purposes which they are intended to answer in the general plan of creation.

This class, notwithstanding its name, *Vermes*, or *worms*, includes a vast variety of animals, as snails, slugs, shells, and their inhabitants, corals, and an indefinite variety of microscopical animals, called infusoria, from the circumstance of their being detected in waters, in which vegetable matter of some kind or other has been steeped. The different orders, which are five in number, are the following:

1. *Intestina:* this order includes worms with a filiform, or thread-like body, of equal thickness, and smooth; also the common earth-worm, the worms found in the intestines of different animals, the leech, and a few others.

2. *Mollusca,* this order contains animals of a simple form, naked, that is, without a shell, with members, or additional parts, not to be found in those of the first order. These members, however, do not answer to the feet, or wings, or fins of quadrupeds, birds, or fishes. In some they are called rays, as in the Asterias, or star-fish; in others, tentacula, or feelers, as in the Sepia, or Cuttle-fish; and in others, as in the Limax, or Slug, they are denominated horns.

3. The third order is named *Testacea,* or worms of a soft and simple form, covered with a shell. The whole order is characterized by the shell, which is a calcareous covering, which each animal forms for itself by a concretion, or exudation from the surface of the body. There are many different genera of shells, and the study of this order of the class Vermes has obtained a distinct scientific name, that is, *Conchology.* This branch of Natural History is very popular,

on account of the elegance and beauty of the shells, and of the easy method of arranging and preserving them. As a branch of science, the objects of conchology are separated into three divisions, viz. (1.) *Multivalves*, that is, shells with many valves; as the *Chiton*, *Lepas*, and *Phloas*. (2.) *Bivalves*, or shells with two valves: as the *Ostrea*, oyster; *Mytilus*, mussel, &c. (3.) *Univalves*, or shells with one valve only, which division is subdivided into those with a regular spire, as the *Argonauta*; the *Nautilus*; the *Helix*, or snail, &c.

4. *Zoophyta*. This order comprehends Composite animals efflorescing like vegetables, included in a calcareous crust. Many thousands of them live together, and are so connected both by their calcareous covering, and their softer fleshy part, as to be considered as a single production. They increase in bulk, and mostly branch out like plants: they may, like plants, be propagated by slips. We have already observed, that this order of animals constitutes a sort of connecting link between itself and the other two kingdoms of nature. It is separated into two divisions: (1.) Those with a hard calcareous stem, of which, among others, the madrepores and millepores are examples. (2.) Those with a softer stem: this division includes ten genera; of which the sponge, the Coralline, and Polypus, are good examples.

5. *Infusoria*. This order has been added to those of Linnæus, to include such microscopical worms as have been discovered in stagnant or other water and fluids. The animals included in it are divided into: (1.) Those that have external organs. (2.) Those without external organs, and flattened: and (3.) Those without external organs, and round.

In mentioning the authors who have treated on the several branches of Zoology, we must confine ourselves to very few: for the bare enumeration of the titles of all the works of high authority on the subject, would fill a large space.

As a popular, instructive, and very useful work, including each branch of Zoology, we may mention "Essays introduc-

tory to the Study of Natural History, by Fenwick Skrimshire, M.D." in two volumes. In the division Amphibia, this author has not followed the improved Classification of Linnæus, but in other respects it cannot be too strongly recommended to young persons. The facts, through the whole, are plain and simple, but striking and interesting; and they lead from animate and inanimate creation to the contemplation of the power, the wisdom, and goodness of the Creator.

"General Zoology, or Systematic Natural History, by George Shaw, M.D. F.R.S." which has been in the course of publication many years, is an extremely valuable work to those who can bear the expense. It commences with Quadrupeds, which are included in the Mammalia of Linnæus, and proceeds in systematic order through the several branches of Birds, Amphibia, Fishes, Insects, and Vermes. The Linnæan arrangement is generally pursued.

A still more popular work by the same author, is entitled "Zoological Lectures;" in these there is a plain illustration of the animal world, according to the Linnæan mode of arrangement, with some deviations.

A very useful Introduction to Natural History is contained in a work published at Edinburgh, in 1801, entitled, "Elements of Natural History," in 2 vols. 8vo.

Another popular, but very expensive work, and without the same regard to classification, is entitled "Zoography, or the Beauties of Nature displayed, &c. by W. Wood, F. R. S." The plates accompanying this work are extremely beautiful and highly finished.

With the works of Pennant and Buffon, every student in Natural History will soon become acquainted: and in those already mentioned, he will find references to all the best writers on the subject. Pennant has been called the English Linnæus, and by many, his classification of the Quadrupeds is preferred to that of the Swedish Naturalist. Edwards, Pennant, and Latham, have all treated of Birds, and their works claim a high portion of praise. Among the authors

who have written on serpents and fishes, may be mentioned Seba, Catesby, Gronovius, Garden, Ray, Pennant, and Donovan. In Entomology, the best English writers are Donovan, and Kirby; from the latter a complete and scientific work is very shortly expected. Da Costa's "Elements of Conchology," is a treatise of much merit: so also are Barbut's "Genera Vermium," and Ellis's "Natural History of Zoophytes and Corallines." An excellent treatise on Conchology is to be found under the word in Dr. Rees's New Cyclopedia. The first four volumes of Turton's Linnæus should be possessed by every English student of Zoology.

MENTAL PHILOSOPHY.

CHAP. XI.

OBJECTS AND UTILITY OF THE SCIENCE, AND GENERAL VIEW OF OUR MENTAL POWERS.

Mental Philosophy—Metaphysics—Mental Philosophy important to Intellectual Culture—to Moral Investigation—to Education—to the Young—to Religion—Mind—Sensation—Ideas—Association—Conceptions — Feelings — Notions — Ideas of Reflection — Memory—Imagination—Understanding—Will.

MENTAL Philosophy, or the *Philosophy of the Human Mind,* is that branch of science, which investigates the laws of the human mind. Its object is to ascertain the properties of the mind, the origin and nature of its various modes of thought and feeling, the ways in which they operate upon each other, and the means by which they are to be cultivated or repressed.

Mental Philosophy is not uncommonly confounded with *Metaphysics;* and the absurdities and futile speculations, which have been classed under the latter, have been supposed by many to belong to the former. *Metaphysics* (μετα τα

φυσικα) comprehends all investigations respecting those objects of human thought, which by sensation alone, could not be brought under the notice of the mind; and it consequently *includes* the philosophy of the human mind: but it is obviously unjust to throw upon this department of metaphysics, the stigma which, if due to any, belongs to those branches alone, which have little or no relation to mental laws and operations.

Whatever relates to the properties of the mind, to the operations of intellect and affection, is of high value in various points of view. The philosophy of the mind, as Mr. Stewart justly remarks, abstracted entirely from that eminence which belongs to it in consequence of its practical applications, may claim a distinguished rank among those preparatory disciplines, which Bishop Berkeley has happily compared to "the crops which are raised, not for the sake of the harvest, but to be ploughed in as a dressing to the land."

The object of *Moral* Philosophy is to shew men their duty, and the reasons of it. It teaches what regulation of the conduct and the affections is our duty, why it is our duty, and how it is to be required. It is sufficient barely to state these objects, to shew at once the subserviency of mental to moral philosophy. The foundations of the science of morals, can only be laid with success on a judicious acquaintance with the principles of the mental constitution. We must know what are the affections in which moral excellence consists, how they are to be formed and cultivated, and how opposing ones are to be repressed or exterminated. And the consequence of actions can be fully shewn only by mental philosophy, or by that experimental acquaintance with the phenomena of mind on which its laws are founded.

A sound and comprehensive acquaintance with the laws of our mental frame, is of incalculable utility in the business of education. It gives to those who conduct it, correct views as to its object. It shews the vast importance of early impressions, of early attention to the culture of habits and disposi-

tions; and it points out the best means for forming those characteristics of intellect and affection, which are essential to happiness and usefulness.

An acquaintance with the grand practical laws of the mind, will supply the young (and particularly those, who are early left to form their plans of action for themselves), with a most useful guide, to preserve them from the "aberrations of folly and the pollutions of vice." They will be led by it to perceive how their present conduct and dispositions will affect their future character and happiness; to perceive the importance of avoiding a frivolous employment of their time, without any end beyond mere present amusement; to perceive the impossibility of indulging in vicious gratifications, without diminishing their means of happiness, and checking their progress towards excellence. They will learn to consider the formation of habits as requiring their utmost circumspection: they will learn what are baneful, what beneficial; what means of happiness should be made of primary value, and what should be regarded as subordinate only. Between the age of seventeen and thirty (earlier or later), the character usually acquires its permanent bias. After the commencement of that important period, the education of the human being usually depends in a great measure upon himself; and a judicious acquaintance with mental philosophy is an invaluable means for the right employment of it: indeed, next to the pursuits of religion, to which it directs, this is the most important means. We shall deem ourselves amply recompensed, if in any of our readers belonging to that period of life, we should succeed in producing an interest in the study of the human mind; in giving them such an elementary acquaintance with its laws, as will enable them to acquire from reading and reflection, and observation, just views of its operations and means of culture; and in inciting them to employ their knowledge in self-correction and self-improvement. To make the study of the human mind fully answer its objects, requires an accurate discriminating judgment, and the habit

of correct and cautious reasoning; but patient reflection and good sense, are alone essential to the beneficial pursuit of mental science; and with these it will in all cases lead to results highly important to individual welfare and usefulness.

The well-disposed young often fall into a desultory mode of reading, and form injurious habits of mind, for want of something to fix their attention. We here present to them an object, which no one can doubt is of high value, and which is deeply interesting to those who pursue it with patient persevering reflection. There is one class whom we feel peculiarly desirous of leading to this object; those of our female readers, who having completed the common round of school-education, are not yet occupied in any employments, which require a large portion of their time and active exertion. Those habits of frivolity and dissipation, which waste the most promising talents, and fritter away some of the most precious moments of life, would be restrained, perhaps altogether avoided, if they had some fixed object of pursuit, particularly one in which every step is useful knowledge. And if called to the duties of parents, how valuable would be their methods of early education! Their efforts would be well chosen and well applied. Those who might build upon their foundation, would recognise the skilful hand of maternal wisdom; they would only have to further, to promote, instead of being obliged to change, to eradicate; and those for whom their efforts were made, when they compared their own happy freedom from destructive errors, and their possession of correct habits of disposition and action, with the condition of others, would bless the well-directed solicitude which had watched over their early impressions, and judiciously guided their affections, desires, and expectations.

We may further observe, that an acquaintance with the principles of this important science, enables us more correctly to appreciate the inestimable value of Christianity, and the strength of the evidences on which it is founded. It leads to the most interesting conclusions respecting the worth of

Christian precepts, and the exalted nature of Christian motives. It shews us how Christianity "reconciles human nature to itself;" and it shews us, that the truth of it rests upon the well known laws of the human mind. It directly furthers the cause of religion in general, by rendering more obvious the reasons of the divine dispensations; and by the various displays of goodness and wisdom, which our mental phenomena present to us. It tends, beyond all other branches of philosophical investigation, "to correct, enlarge, and exalt our conceptions of the attributes and character of the Supreme Being, and to lay a foundation for the most exalted and rational piety."

In fine, the well-directed study of mental philosophy calls into action, and improves, the highest intellectual faculties; and while it employs the powers of the mind, it suggests the best means for their culture, and the best mode of their direction. It enables us to trace the intricacies of our own hearts, and points out the proper discipline for their correction: it discloses the real excellencies of the mind, and guides us in our efforts for the attainment of them. Pursued with proper views, and in a proper manner, it lays the best foundation for the highest degrees of intellectual, moral, and religious improvement.

GENERAL VIEW OF THE POWERS OF THE HUMAN MIND.—That, whatever it be, which thinks, and feels, and wills, is called *mind:* that part of the human being, which thinks, and feels, and wills, is called the *human mind.* This is the most limited acceptation of the term. In common language, and often in philosophical writings, it is employed more widely; including not only the conscious or percipient principle, but that, whatever it be, which supplies the mind with the immediate objects of consciousness: as when we say, 'That man has a great fund of useful ideas stored up in his mind;' meaning, that the causes of those ideas remain in his mind, ready for excitement, either by direct exertion or

by the influence of external impressions, or of other ideas. Without entering into any metaphysical distinction respecting the nature of the mind, we shall employ the term in this wider acceptation.

If we hold a luminous body before the eye, the rays of light from it produce a change in the state of that organ, and this produces a *sensation* in the mind. In like manner the scent of a rose, the sound from a bell, the taste of an orange, the blow of a stick, produce changes in the organs of sense; and these produce *sensations* in the mind. With the sensation, will almost always be found united ideas respecting the externality of the object, its qualities, situation, &c.; but when we speak of *sensations*, as such, we must confine our attention to the simple effect of the objects causing them; such as it would be in the mind of a child, which has as yet formed no ideas. The power or property of the mind, by which it is capable of receiving sensations from external objects, is also called SENSATION: to avoid ambiguity, it might be termed the *Sensitive Power*.

Sensations cease soon after the exciting cause is withdrawn; but if they have been produced with sufficient vividness or frequency, the causes remain in the mind of mental changes, (similar in kind to the original sensation,) which can recur when no change is produced in the organ of sense. These mental changes, (which may be considered as the relics of sensations,) are called *ideas;* and when in the state in which they are retained from sensations, without being connected with any other ideas, they may be called *simple* or *elementary ideas.*

The various elementary ideas derived from sensations, become connected with one another, so that the recurrence of one, or of its corresponding sensation, will bring on another; and in many cases they are combined together, and so perfectly blended together, as to appear one uncompounded idea. When one idea is thus formed of many simple ideas it may be called a *complex idea.*—In like manner complex ideas may be *connected* or *compounded* with others. The power of the

mind by which these connexions and compositions are produced is called ASSOCIATION. The act of connecting or combining, is also denominated *association;* as well as the group so connected or compounded. The power might therefore be well termed the *Associative Power.*

When ideas are so little compounded with others, that they resemble sensations, they are still termed *simple ideas;* but it is more convenient to call them *conceptions,* according to Mr. Stewart's use of that term, to denote a distinct idea of an absent object of sense: thus the distinct picture I can form in my "mind's eye," of a friend's countenance, or of a prospect, &c., is called a conception. Those ideas which from their remoteness from sensation, have no resemblance to conceptions, may be termed *notions;* such as those we have, when we use the terms *virtue, justice, &c.*

Pleasurable or painful sensations leave relics behind them, which Hartley includes under the general denomination of *ideas.* This however is little accordant with the common acceptation of the term *idea;* and it is usually better to give the name of *feelings,* to the pleasures or pains which may exist in the mind without any present sensation.

The associative power has the chief share in the formation of the *mental feelings,* (the affections, passions, desires, emotions, &c.) from the relics of sensation, and their combinations. The mind may, by different intellectual operations, modify the feelings, and transfer them from one object to another; and the culture, refinement, or suppression of them, greatly depends upon various voluntary acts, which may bring them, to a considerable degree, under the power of the mind: but in a great measure they are formed without its direct efforts, and almost without its knowledge. The same may, in a more limited extent, be affirmed with respect to our *notions.* But these depend, much more than our feelings, upon the direct exercises of the *understanding;* and by means of this power, aided by association, ideas are formed, which could not be derived from the operations of association alone: such

are those of *relations.* One class of our ideas is, in its origin, still more independent on the associative power, viz. those which are derived from the attention of the mind to *its own operations, states and feelings;* such as *judging, willing, recollecting, indecision, joy, grief,* &c. Of these we can form such distinct ideas, that they may with much propriety be classed with *conceptions;* and without such distinct idea of any individual operation, &c., we have *notions* connected with the terms *reasoning, willing, reflection,* which must have been derived from attention to those operations, and could have been formed in no other way. These conceptions and notions, are termed *ideas of reflection:* the former are the simple elementary ideas; the latter are complex ideas, formed from them by association.

The associative power operates among all the different classes of our ideas, combining the more simple into more complicated notions, and connecting them with one another by various principles of union; some arising from the mere mechanism of the mind, independently of the exercises of the understanding; and others originating in the understanding.

The mind has not only the power of deriving ideas from the different sources already indicated, but also of retaining them, (or rather the causes of them,) and of recalling them to its view. These operations of *retention* and *recollection* are referred to the MEMORY, or that power by which ideas are retained, and by which they recur, or are recalled, in that state and order in which they were received. In the operations of this power, association has so much influence, that they might, in a variety of cases, be very conveniently referred to it.

The mind cannot form simple elementary ideas of sensation without the corresponding sensation; but, under considerable limitations, it has the power to arrange and combine them in various ways, so as to form new combinations or trains of ideas. We can *form conceptions* of scenes and circumstances which we have never witnessed; and we can *imagine* situations,

events, and so on, which have never actually existed. This creative, or productive power of the mind, is called the IMAGINATION. Some writers call it the *Fancy*, using the two terms without discrimination; but the latter appears most appropriate to the recurrence of vivid ideas, without regard to the order of any past actual occurrence of sensations or ideas. The *fancy* is simply one mode of association: the *imagination* clearly is, in a great measure, influenced by that power; but many of its operations, especially those directly voluntary, render it necessary to speak of it as a distinct faculty.

These intellectual powers, or faculties, are all subservient to the exercise of the UNDERSTANDING, and some of their operations might be referred to it: but it is much more convenient to limit the term to that power of the mind by which it contemplates ideas and sensations, (considered as such,) and its own various operations; by which it discerns the relations which exist among the objects of perception and thought—pursues truth—and assents to propositions, or dissents from them.

Many of our mental operations take place without any intentional effort or volition. But the mind can often direct its operations; it can will, or determine, to judge, to reason, to employ the causes which excite feeling, to produce bodily motion, &c. That power which it has, in certain cases, of producing acts and operations, which are called voluntary, is termed the WILL. As the exercise of this power is concerned in all internal or external acts, which are in any degree voluntary, it is not easy to consider it as distinct from them: it is however preferable to regard it as a separate power of the mind.

The operations of the mind are often so complex, and partake so much of the leading characteristics of different faculties, that it is not always easy to determine to which they belong. And from similar causes, the distinction of the intellectual powers is variously stated by different writers. This produces considerable difficulty to those who are beginning

the study of mental philosophy. We have given that arrangement which appears the simplest; and if our readers reflect on what passes within them, sufficiently to enable them to gain clear ideas of the nature of the leading operations of their mental powers, they will, we hope, find little difficulty in following us in our outline of mental philosophy; and that this will be found a useful introduction to the study of this important branch of knowledge.—We shall therefore endeavour to give a brief view of the leading phenomena of the mind, which are referrible to the heads of SENSATION, ASSOCIATION, UNDERSTANDING, and WILL; referring them for MEMORY and IMAGINATION to the truly excellent chapters of *Dugald Stewart* on those faculties; in which they will find abundance to instruct and delight, and little that is in any way objectionable. They will also derive great advantage (after perusing our chapter on Association,) from the study of those parts of *Hartley* which relate to the memory and imagination. His ninety-first and ninety-second propositions afford less palatable, but not less wholesome food for the understanding, than Dugald Stewart's elegant and highly important investigations respecting the *influence* of the imagination. On the *phantasms produced by disease,* there is an interesting detail of facts in one particular case, in Nicholson's Journal, 8vo. vol. xv. p. 288—296; and in the same volume (and also in the Manchester Memoirs, vol. i. N. S.) is a very valuable paper on *Reverie* considered as connected with Literature. In addition to these, we refer the reader to the article MEMORY in Dr. Rees's New Cyclopedia; and to the division on *Memory* in INTELLECTUAL EDUCATION, in the same work. From these several sources they will probably derive all the information that they will require; and an *introduction* to Stewart's chapters on those faculties will not be necessary, after the perusal of the Chapter on ASSOCIATION, in this volume.

CHAP. XII.

SENSATION.

Vibrations—Perceptions—Sense of Feeling—Taste—Smell—Hearing—Sight.

THE bodily organs of sensation are the external organs, the nerves, and the brain. The external organs of sense are usually classed under five heads, the *sight*, *hearing*, *feeling*, *smell*, and *taste*. The sense of feeling might with convenience be divided into two or three; because the classes of sensation, which are referred to this sense, differ considerably in themselves, and in the external causes producing them.

Vibrations.—How it is that the changes produced in the external organs of sensation affect the mind, is a point respecting which we have, at present, no means of knowledge. Different hypotheses have been invented to account for it; but even if correct, they explain little more than the mode in which the external impressions are conveyed to the brain: how the changes in the brain affect the percipient principle, is utterly unknown, and, in all probability, will always continue so.

Dr. Hartley was of opinion, that the impressions made upon the external organs of sense produce vibrations in the minute parts of the nerves, which are propagated to the brain, and there excite sensations in the mind. This hypothesis was suggested by Sir Isaac Newton; but it was greatly extended by Hartley, who thought that it accounts for all the leading phe

nomena of sensation and association. It is much to be regretted, that this great philosopher burdened the important doctrine of association with the hypothesis of vibrations; they are really independent of each other: and those do Hartley and his philosophical system great injustice, who represent the matter in any other light. We do not believe that any hypothesis as to the corporeal occasions of thought, can, in the present state of our knowledge, really explain the operations of thought: but if any of our readers wish to know more of Hartley's hypothesis, we may refer them to Mr. Belsham's Elements of the Philosophy of the Mind, p. 38—55. In Dr. Reid's Essays on the Intellectual Powers, Essay II. chap. 3. they will find the arguments of that philosopher against it. And we think it right to add, that Haller (the great physiologist,) maintained, that it is totally incompatible with the nature of the nerves and medullary substance.

Of Perception.—To perceive the influence of each sense in forming our notions and feelings, it is necessary carefully to distinguish between the mere sensation, and those ideas which are, by association, so connected with it, as to appear at first view a part of the sensation.

By the laws of association, many simple ideas of sensation, received through the medium of different senses, become connected, and at last blended together, so as to form one very complex, though apparently uncompounded idea. The complex idea, or its component simple ideas, may have been the direct objects of the operations of the understanding; and thus the complex idea may have been farther modified. Now this complex idea is often recalled to the mind by a corresponding sensation; and, by association it becomes so connected with that sensation, that the complex idea itself is often mistaken for a part of the sensation. For instance, the sensation produced by the impression made by a *globe* on the sense of sight, is, as can be proved, nothing more than that produced by a *circle*, with certain variations of light and shade; yet, immediately on the sensation being perceived, the ideas of its

solidity, of its hardness, its magnitude, and of its being something external to one's self, immediately rise up in the mind in one blended form: by their complete coalescence they appear to be one; and by their immediate and constant connexion with the sensation, they appear to the mind as a part of the sensation. Indeed, there are comparatively few people who ever think that the sensation derived from the sight, is nothing more than what is derived from a minute picture delineated on the back part of the eye called the retina. Things appear to us, at one glance of the sight, to be solid or flat, to be near or distant, to be large or small, to be conjoined with other things or separate from them, to be parts of our own frame or external to it, &c.; and all this we appear to learn by the sight alone: but the fact is, that all these ideas are derived from another sense at various times, and altogether blending together, and arising the moment the visible impression is communicated, they appear part of the visible impression. "The visible appearance of objects," as Berkeley observes, "is a kind of language serving to inform us of their distance, magnitude, and figure:" no sooner are these signs presented to the mind, than, with the rapidity of lightning, the ideas associated with them succeed, and appear to have been communicated by the sight, and to be in reality a part of the sensation.

When the sensation produced by an external object, is so closely united with ideas which have been previously derived from sensation, and modified by the operations of the understanding, that the whole shall appear to be one feeling, apparently derived immediately from the external impression, the whole together,—*the sensation and the complex idea*,—is called a *perception*. And by the *faculty of Perception* we understand that compound power, (or rather combination of powers,) by which perceptions are formed of external objects. The real nature of perception is greatly misunderstood; and indeed it cannot be understood without an acquaintance with the influence of association in forming complex ideas, and in

enabling sensations at once to bring them into the view of the mind.

Admitting the powers of *sensation* to be in an equally sound and vigorous state, yet it is obvious that the *perceptions* may vary very greatly in different individuals, and in the same individual, at different periods. Suppose a watch to be subjected to the observation of three persons, whose organs of sense are alike healthy and vigorous: the one, a very ignorant person, totally unacquainted with its purposes and movements; the second, a well informed person, not however possessed of any acquaintance with the particular mechanism; the third, an artist, minutely and completely acquainted with it: the sensation may be precisely the same in all instances; the picture upon the retina may convey to the mind an equally impressive *sensation* of the object; but how different the *perception!* The first sees a number of minute objects, which attract his attention perhaps by their beauty and regularity; but nothing more: he has no idea of their subserviency to each other, or of their general use: there is little more in his case than sensation; indeed we may say, nothing more than sensation, besides those associated perceptions which so soon become connected with every impression from external objects, and to which we have already referred. The second, from his general knowledge of mechanism, has some ideas excited by the sensation, of use and connexion; but he cannot discern the specific kind of connexion, nor how each part tends to answer the end of the whole. If he set about to study the mechanism, he subjects each part to minute examination in its structure and connexions; and by degrees may acquire an acquaintance with the whole, which, on a subsequent inspection, would give him an immediate distinct perception of the parts and purposes. What he thus acquires by laborious and patient examination, the third saw at once. His perceptions have long been cultivated by daily attention to the movements and their dependencies, by studying their defects and excellences, by the actual formation of their various parts, and

the structure of the whole: and a great number of ideas produced by such observations and operations become so intimately united with the sensation, that at last this at once excites them, and thus he sees, or, (more correctly,) perceives what lies totally out of the reach of the observation of others.

Sensations derived from the senses of Feeling, Taste, Smell, and Hearing.—All the external organs of sensation communicate to the mind materials for its notions and feelings; and it is probable that elementary pleasures or pains from every organ enter, more or less, into the composition of our most refined mental feelings.

The *sense of feeling* differs from the other senses, in belonging to every part of the body, internal or external, to which nerves are distributed: the term *touch* is most correctly limited to the sensibility which is diffused over the surface of the body, and exists in the most exquisite degree, at the extremities of the hands and lips.

This sense is of the utmost importance to man, considered as an intellectual being. It furnishes us with all our elementary notions respecting the real qualities of substances; and it is the sole medium by which we gain a knowledge of external objects as such. It is by the touch, (and originally by the touch alone,) aided by the power of bodily motion, that we distinguish our own bodies from other substances that surround us, and from the impression which every one has, that the objects, which affect the sight, the hearing, &c. are external.

The sense of feeling conveys to us the sensations of heat, hardness, solidity, roughness, dryness, motion, distance, figure, &c.; and all those corporeal feelings which arise from a healthy or diseased state of the nerves, and of the part of the body to which they belong.

The pains of this sense are more numerous and vivid than those derived from any other sense; and, therefore, have the greatest share in the composition of our mental pains. Its

pleasures on the other hand, are, in general, faint and rare, in comparison with others.

The *sense of taste*, (considered as extending not only over the mouth, but through the whole alimentary duct,) conveys sensations of flavours, and of hunger and thirst. It undergoes remarkable changes in passing from infancy to old age; partly from the universal effect of custom, to diminish the vividness of sensations and feelings, and partly from the influence of associated circumstances. Its pleasures are considerable, especially in the early part of life, and constitute one grand source of our elementary mental pleasures. Its pains are only such as are necessary to prevent excessive abstinence or gratification, and the employment of improper food. The most common are those arising "from excess, and the consequent indigestion. This excites and supports those uneasy states which attend upon melancholy, fear, and sorrow."

The *sense of smell* is nearly allied to that of taste. Its pains are obviously designed to assist us in the proper choice of food, and to excite us to avoid such vapours, as may render the air injurious to health. Offensive odours do also, in various circumstances, contribute to produce the feelings of shame, decency, &c. Its pleasures, besides aiding those of taste, contribute to the formation of some of those mental pleasures which are derived from the beauties of nature.

The *sense of hearing* furnishes us with sensations of sound; and many of its simple pleasures aid in the formation and growth of the mental pleasures. By association, sounds become the signs of ideas; and they are of essential service in the formation or reception of our most complex notions. The more refined pleasures of this sense are greatly indebted to association; and in their turn contribute, in an important degree, to exalt and refine the system of feeling. The early loss of sight only *impedes* the progress of the mind from sensation to intellect and affection: those who have never heard, have much greater disadvantages to undergo. The use of words is neces-

sary to the full improvement of intellect, and the enlargement of affection; and therefore, during the early periods of mental progress, the ear is of much more importance to us, as spiritual beings, than the eye. The means of knowledge are, however, it is evident, most abundantly increased by the possession of sight.

Sense of Sight. Rays of light proceeding from every point of the visible object, enter the eye, and form upon the retina an exquisitely beautiful and distinct, though minute picture of the object. The optic nerve is affected by this impression on the retina; and, by some unknown means, communicates to the mind the sensation of sight.

If this sensation be considered unblended with the relics of other sensations, we find that it is merely what can be communicated by the picture on the retina. The sensation of *colour* can be thus, and thus alone communicated; and this is the only sensation which can be considered as appropriate to the sight.—The sensation of *figure* can be communicated by the sight, but only of figure in two directions, length and breadth; for the picture on the retina can have only those two dimensions.—The sensation of *magnitude* can also be thus communicated, but not of real magnitude; for a sensation of real magnitude cannot be conveyed by a picture which is almost indefinitely smaller than the real object. To use the illustration of Adam Smith: "If you shut one eye, and hold immediately before the other a small circle of plain glass, of not more than half an inch in diameter, you may see through that circle the most extensive prospects, lawns, and woods, and arms of the sea, and distant mountains. You are apt to imagine that the visible picture, which you thus see, is immensely great and extensive; but it can be no greater than the visible circle through which you see it. If, while you are looking through the circle, you could conceive a fairy hand and a fairy pencil to come between your eye and the glass, that pencil might delineate upon that little glass, the outlines of all those extensive lawns, and woods, and arms of the sea, and distant mountains, in the dimensions

in which they are seen by the eye." Again, it is obvious that however large, or however small the field of view, the picture occupies an equal extent upon the retina.—Similar observations might be made with respect to *distance*. The organ of sight can convey only that sensation of distance, which may be produced by a minute picture on the retina; that is, nothing but the sensation of the distances of the different parts of the picture, which may bear no proportion to the real distances, and can only be in two directions.—Similar things may be said of *motion*, that is, change of position. The visual sensation of motion is merely that produced by the motion of different parts of the picture on the retina.

The fact is, that not the object itself, but the picture formed upon the retina, is the immediate object of the sight. Without the sense of touch, it is probable that the picture would never have conveyed ideas of real figure, magnitude, motion, or position; still more, that it would never have conveyed the idea, that external objects produced the picture. Of *colour* it does convey sensations which do not receive correction from the touch, and which can only be acquired by the sight. Persons completely blind have been known to distinguish objects of one colour from those of another; but this is by the feel of the surfaces of those objects. If they have never at all possessed sight, though they may speak of colours, and distinguish coloured objects, and even have a remote idea of the causes of our sensations of colours, yet they can have no sensations, nor consequently ideas, of colours. Mr. Locke mentions a blind man, who said that he imagined the colour of scarlet resembled the sound of a trumpet.

The limits here stated of the direct power of the sense of sight, may appear strange to those who have not been accustomed to distinguish between the *sensation*, and the *perception* of which the sensation forms a part. There are, however, numerous circumstances which prove the point; the most satisfactory are those attending the obtaining of the sight, at a period when recollection can register the sensations. One such

case fell under the observation of the able Cheselden, and we shall state some of the principal circumstances of it. Mr. Cheselden couched a youth of thirteen years of age. When he was allowed to use his sight, all objects appeared to him alike to touch his eyes, as the things, which he felt, touched his skin. He considered solid bodies as planes differently coloured; and when he had learned to distinguish solids by their appearances, he was greatly surprised, when examining the pictures of solids, to find all the parts plain and smooth like the rest; he asked which of his senses deceived him, his sight or his feeling? Being shewn a miniature of his father, which was painted on a watch-case, he at once perceived that it was a representation of his father, but expressed great surprise that so large a countenance could be contained in so small a space; it appeared to him as impossible, as for a pint to contain a hogshead. Mr. Ware published in the Philosophical Transactions of 1800, a case which seemed to militate greatly against Mr. Cheselden's conclusions: his patient had from the first, ideas of distance and form. But Mr. Ware himself furnishes a solution of this difficulty; for we find from his paper, that his patient had always been able to distinguish light and vivid colours from shade.

Sensations of colour are, in the early parts of life, very vivid, and assist considerably in the formation of our mental pleasures; but the other sensations derived from this sense, are principally important to us, as being by association the signs of the ideas derived from the touch; and, from their distinctness, well calculated to serve as the connecting bond of union, and to bring those ideas again into the view of the mind. The visual sensations, of themselves considered, are rarely the objects of reflection; we seldom even think of them; and while we appear to give to the visible appearances of objects, our minutest attention, we are, in fact, attending only to the tangible qualities, of which the visible appearance is the sign. Were it not therefore for association, the sight would be of little more use to us than a beautiful picture of objects with

which we have no concern. But consider its value in connexion with association, and it must be regarded as the most perfect, and the most permanently valuable, of all the senses. The information acquired by the touch, is obtained slowly; and the sensations must be continually repeated, in order to acquire information respecting objects: but the sight takes in a vast variety of objects, and, almost at a glance, can distinguish what is necessary to be known respecting them. Its sensations recall the past impressions derived from the touch, and at once suggest the size, the shape, the distance of their various objects. "If a man," says Reid, "were by feeling to find the figure of the Peak of Teneriffe, or even of St. Peter's at Rome, it would be the work of a life-time." Besides, its discovery reaches farther than the touch could carry us; it enables us to range through the vault of heaven, and determine the motions of the heavenly luminaries. It traces in the countenance the workings of the mind; it displays the passions and affections of the soul. With association it is every thing. Without its aid, it would be useless as the bright fleeting visions of sleep.*

* The reader who wishes to enter particularly into the phenomena of sensation, may consult Reid's Inquiry into the Human Mind, and Hartley's Observations, Prop. 23---73, omitting such as relate to vibrations. A judicious summary will be found in Belsham's Elements, p. 56---105. Respecting the curious class of phenomena, termed *Ocular Spectra*, see the end of the second part of Darwin's Zoonomia.

CHAP. XIII.

OF ASSOCIATION.

Locke—Hartley—1. Classes of Connexions—2. Laws of Connexions, &c.—Strength and Durability of Associations—Disunion of them—Law of Transference—Relations—3. Composition of Ideas—Mental Feelings—4. Affections, &c.—Filial Affections—General Principles respecting the Affections—Influence of Habit on Sensibility—Disinterested Affections.

ENOUGH has been already stated, to shew the great importance of this principle. There is scarcely an operation of thought in which association is not concerned; and in every department of feeling its agency is indisputable.

Mr. Locke appears to have been the first who employed the principle of association to account for the aberrations of judgment and affection, and for customary connexions of ideas; but he does not seem to have been at all aware, that all our ideas, except those of reflection and the elementary ideas of sensation, are in reality formed by the influence of the same principle, either alone or under the guidance of the understanding; that all our affections, and our mental pleasures and pains, are nothing more than the relics of sensation variously combined by association. This truth was fully brought into view by Dr. Hartley, in his Observations on Man. Dr. Hartley was eminently qualified for the successful pursuit

mental science; for with habits of patient, persevering investigation and observation, a correct and penetrating judgment, and an extensive acquaintance with the most important branches of human knowledge, he united those moral qualities, the want of which has, more than any thing, tended to cloud the mind, and prevent the intellectual eye from discerning important truth. Hartley has unfortunately blended with his grand principles, an hypothesis respecting the physical causes of thought, which is of little or no value: in some cases he has carried too far the application of the grand law of association; and, in particular, he has too much neglected the effects produced on its agency by the exercise of the understanding. Nevertheless his work is a treasury of comprehensive and judicious observations, and accurate and profound investigations, respecting the human mind, of unrivalled excellence and importance: and his principles, while they satisfactorily explain a vast variety of our mental phenomena, are an invaluable guide in moral culture.

In endeavouring to lead our readers to an acquaintance with some of the most important phenomena of association, we shall first give a view of the classes and laws of *connexions;* and then state some of the chief facts relative to *compositions*, and the formation of our compound notions and feelings.

§. 1. *Classes of Connexions.*

First: a *sensation* may be associated with other *sensations*, *ideas*, and *motory changes* (i. e. such mental changes as produce muscular action, whether these be directly voluntary or not.)

(1.) A *sensation*, after having been associated a sufficient number of times with another *sensation*, will, when impressed alone, excite the simple idea corresponding with that other sensation.—Thus the names, smells, tastes, &c. of external objects; suggest the idea of their visible appearance; and the sight of them suggests their names, &c. In the same manner, a word half pronounced excites the idea of the whole word;

the mention of the letters *a, b,* suggests the idea of *c, d,* &c.; the sight of part of an object suggests the idea of the whole; and the sight of one object recalls the visual idea of other objects which have been uniformly or very frequently seen with it.—Innumerable other instances might be given with little trouble; but we shall mention only one more, which may assist some of our readers in accounting for certain cases of apparitions. A youth was one day hastily passing by a room in which a very excellent friend had usually sat, in a particular chair, and in a particular part of the room. His thoughts were not much engaged; and the sight of the chair excited in his mind a vivid conception of his friend as sitting in that chair. The friend had been dead some weeks; but without reflection, he came back for another vision, but in vain. Where such conceptions are vivid and easily excited, they frequently lead those who are inattentive to their sensations, to suppose that they actually saw and heard, at a particular time, what they did not then see or hear.

(2.) *Sensations* become connected with *ideas,* so that the repetition of the sensation will excite the connected idea.—Of this case of connexions the following will serve as examples. Words associated with ideas, will readily excite them even when very complex: the words *hero, philosopher, justice, benevolence, truth,* and the like, whether written or pronounced, immediately call up with precision the corresponding ideas.—The hearing of a particular national tune, is said to overpower the Swiss soldier, when in a foreign land, with melancholy and despair; and it is, therefore, forbidden in the armies in which they serve. The sound recalls various heartfelt recollections; the idea of the peace, and the freedom of their country, of the home from which they are torn, and to which they may never return.—What trains of interesting thought and feeling are usually called up in the mind, by the sight of those scenes of early pleasure, where passed the years when novelty gave charms to every sensation, to every employment of the faculties, when hope presented no prospects, but what were decked in

"fancy's fairy frost-work," and present joys precluded all regret for the past.

(3.) *Sensations* may become connected with *motory changes;* so that the sensation will excite the corresponding muscular action, without the intervention of that state of mind which is called will.—A person automatically (that is, without volition), turns his head towards any one who calls him by his name. When the hand of another is rapidly moved towards the eye, we shut the eye without thinking about it, or even being conscious of it. When copying from any book, if a person is very familiar with the employment, the appropriate motion of the fingers immediately follows the impression produced by the appearance of the word. In the same manner the visible impressions derived from musical notes regulate the motions of the performer. "While I am walking through that grove before my window," says Darwin, "I do not run against the trees or the branches, though my thoughts are completely engaged on some other object:" the sensible impression produced by the objects around, excite in the mind the appropriate connected motory changes, and these the action of certain muscles.

Secondly; Ideas may be connected with *sensations, ideas,* or *motory changes.*

(1.) An *idea* associated a sufficient number of times with a *sensation,* will excite the simple idea belonging to that sensation.—Thus the ideas, whether simple or complex, which have been sufficiently associated with names, excite the ideas of their respective names. Hence it is, that we find ourselves continually thinking in words; that is, the trains of ideas which pass in our minds, are accompanied with their corresponding expressions, when those expressions are familiar to us: and it may be remarked, that the habit of thinking in words is one which contributes greatly to accuracy and facility of thought, and therefore one which the young reasoner will do well to cultivate.

(2.) Next, an *idea* associated with an *idea,* (whether no-

tion or feeling), will excite that idea. Thus the idea of benevolence will excite that of merit; of courage, that of honour; of great talents, that of respect; of cruelty, that of horror; of meanness, that of contempt.

(3.) Again, an *idea* associated with a *motory change*, will excite that motory change, (and its consequent muscular action.)—Thus, the desire to perform a particular action will produce the corresponding voluntary motion of the limbs; joy produces a pleasing cast of countenance; fear excites trembling; and horror, distortion. In the same manner, when we are employed in committing our thoughts to writing, the idea of the words which we intend to commit to paper, if the character be not peculiar, or novel, will immediately suggest, and be followed by, the appropriate motion of the fingers; and this without the intervention of volition, sometimes without even the consciousness of the motory changes, or of the muscular actions produced by them. So also in speaking, unless some difficult pronunciation occur, the muscular actions requisite for the formation of the sounds, follow immediately the conception of the words, without the intervention of the will.

Thirdly; Motory Changes, (and their correspondent *Muscular Actions)*, may be connected with *sensations*, *ideas*, and other *motory changes*.

(1.) *Muscular actions* may be associated with *sensations;* that is, when muscular actions have been sufficiently long associated with sensations, the repetition of the muscular action alone will excite the simple idea belonging to that sensation. Thus the action of dancing will bring to mind the conception of the music with which it has been often accompanied. Again, children often accustom themselves to particular motions of the limbs, while committing to memory, or while repeating what they have learnt; and those muscular actions in many instances become necessary to their correct and ready recollection, and even to their recollection at all. Addison (says Miss Edgeworth), represents, with much hu-

mour, the case of a poor man, who had the habit of twirling a bit of thread round his finger; the thread was accidentally broken, and the orator stood mute.

(2.) So again *muscular actions* may be associated with *ideas;* that is, when muscular actions have been sufficiently long associated with ideas, those muscular actions will excite those ideas. Thus dancing will introduce cheerfulness into the mind. So particular muscular actions have, from habitual connexion, a tendency to excite certain trains of thought or states of mind: those who have been accustomed to one posture while studying, find it difficult to study so well in any other posture; and persons who, while engaged in deep meditation, have been accustomed to any little motions of body, find the continuance of those motions requisite for the continuance of their abstraction of mind. It is upon the same principle, that certain postures of body have a tendency to excite those feelings which all should have when addressing the Supreme Being.—The cases, however, in which any muscular action introduces ideas either simple or compound, are much less numerous than those in which sensations and ideas introduce muscular actions. In fact it is not the usual order of association; and besides, it is sometimes very difficult to say what effect is produced by the muscular action itself, and what by the sensations which generally accompany muscular action. In the next case the point is clearer.

(3.) *Muscular actions* become connected with other *muscular actions,* (that is, the motory changes which produce the one, with those which produce the other); so that the former may introduce the latter without the intervention of the will. —If different muscular actions are produced together, they are called *synchronous;* if one immediately follows the other, they are called *successive;* and the association is in like manner termed synchronous or successive.—The motions of the hands when a person is playing upon the piano-forte, the motions of the hands and feet in weaving and in spinning, and various other muscular actions which will readily suggest

themselves to the reader, may be stated as instances of *synchronous* associations of muscular actions. The motions of the organs of speech in reading or speaking, of the feet in walking, and of the fingers in writing, are instances of *successive* associations of muscular actions.

(4.) These nine cases of the association of sensorial changes, are comprehended by Hartley in the following general theorem: "If any sensation A, idea B, or muscular motion C, be associated for a sufficient number of times with another sensation D, idea E, or muscular action F, it will at last excite *d*, the simple idea belonging to the sensation D, the very idea E, or the very muscular action F."—The sensation itself cannot of course be re-excited, because that depends upon the presence of the object of sense; but sometimes, as in the instance already stated, the simple idea belonging to a sensation is so vivid, that it equals, if not surpasses the original sensation.

§. 2. *Laws of Connexions.*

I. The *strength and durability* of associations depend principally upon three causes; (1) the vividness of the connected ideas, &c., and the degree of attention which has been given to them in connexion;—(2) the frequency with which they have occurred in connexion;—and (3) the predisposition of the mind, and the prevailing cast of the associations already formed. These we should gladly illustrate; but it is probable that the reflecting reader will easily do it for himself.

The attentive consideration of these principles will at once shew, how important it is that those who have the care of education, should seize the happy moments when circumstances have peculiarly interested the mind, to connect with them those related maxims of prudence, benevolence, and piety, which so introduced may have a lasting effect in regulating the dispositions; but which, if brought in a form less interesting, would have no permanent bond of union, and would soon be obliterated.—Hence, too, the importance of instilling into the mind those principles which are designed to

have a constant operation on the thoughts, and feelings, and conduct of life, in such a form that they shall become connected with the thoughts and feelings which have already a firm hold in the mind, and thus be brought into view and excited into action much more frequently and uniformly.

Where there are associations of a contrary tendency, the production of a new association implies the destruction of the old one; and this is one reason why persons who have passed the prime of life, feel it so exceedingly difficult to acquire new associations dissimilar to those already formed. Hence it is, that all those improper biases which oppose the best regulation of thought and feeling, should be carefully shunned; and all those associations carefully prevented, which lead the mind away from God and duty, or which simply check the reception of those which accord with the dictates of religion. They do more than directly injure by their own existence; they injure also, and this in no small degree, by preventing the formation of those associations which directly prompt to the course which duty points out.

An acquaintance with these principles leads us to the direct method of confirming associations which are essential to our well-being: suppose, for instance, the connexion of a regard to the will of God, with our conduct. We should endeavour to connect, as much as possible, those pleasurable feelings which have a tendency to strengthen the links of union; we should cultivate the connexion by frequently, and indeed continually, bringing it into action; and we should carefully cultivate those related states of mind, which have a tendency to foster and strengthen the connexion. To avoid weakening it, we should be careful not to associate any contrary trains of ideas, (for instance we should never attach feelings of ridicule to any thing connected with religion): and should watchfully avoid those breaks in the association, which will follow neglect in its cultivation. And it is a most satisfactory idea, that if vicious associations may be formed so strong as almost to lie beyond the power of the individual to annihilate them,

virtuous associations may also be formed so vigorous and permanent, as to bid defiance to time and to temptation. These shall survive the wreck of nature, and shall adorn the mental fabric, when this world, and all its sorrows and enjoyments, shall be no more.

II. As associations are necessarily formed, and frequently without any volition on the part of the individual, in consequence of the circumstances already mentioned, it is another very important principle, that an *association may be destroyed*, by the formation of other counteracting associations, or by the steady prevention of its repetition. These causes are sometimes brought into action intentionally, for the purposes of moral culture; but they often operate without any direct efforts on the part of the individual.

Those associations which may unfortunately exist in the mind, unfavourable to the formation and exercise of good dispositions, may be weakened, (gradually, indeed, but certainly weakened), and at last destroyed, by the steady culture of opposite associations. That conduct to which pious benevolence prompts, may acquire so attractive an appearance, that ideas of difficulty, of pain, of ridicule, which may have been attached to it, and which may have impeded its exercise, will gradually give way to those which the divine approbation affords, of present peace and future happiness.—But there is not always time for this slow procedure. It may be necessary for individual happiness, that the baneful association should be destroyed, without one repetition of it to confirm its power. To the general culture of opposite associations, must then be added a steady, careful prevention of the introduction of the connected thoughts and desires. Situations must be avoided, words disused, company shunned, which have a known tendency to introduce a train of thought leading to the first link of the chain which we wish for ever separated.

When we hold it out as a grand law of association, that connexions may be disunited by forming opposing associations, and by preventing their repetition, we would by no

means represent it as in general an easy, or as in all cases a practicable task.—When associations have long been formed, and often repeated, particularly where they accord with the general bias of the mind, they often bid defiance to the most strenuous exertions of the individual. If he could for a long time prevent their repetition, and successfully cultivate opposing associations, the most inveterate associations would by degrees lose their power; but when associations have been strengthened for a long period of time, by being frequently brought into play, and connected with other active associations, and at the same time accord with the prevailing disposition of the mind, the prevention of their repetition, and the culture of opposing associations, is scarcely practicable. These things may be viewed in various lights, some gratifying to the mind, some which must urge every thoughtful person to shun the formation and culture of those associations which he must some time or other wish to break. While they teach us to be assiduously careful to prevent all such, they also shew us that those which we must wish to cherish, may, as well as others of a contrary character, become invincible; and while they direct those who have the charge of the young, carefully to cultivate the tendencies to feeling and action, which may serve as a check upon improper associations,—while they direct them carefully to prevent those which may acquire a despotic rule in the mind, to the destruction of peace and virtue,—they also diminish the anxiety which we are sometimes prone to feel, when we find ourselves unable to mould the mind exactly to that standard of thought and feeling which we wish.

III. Another important principle respecting the associative power, is, that associations are, in a vast variety of instances, formed by means of intermediate links: this mode of its operation may be termed the *law of transference*. In stating it, we shall use the term *idea* in the Hartleyan sense, to denote every internal feeling except sensation, whether simple or compound, whether or not accompanied with pleasure or pain. The law, to which we have referred, may be thus stated. One

idea may become connected with a second, by means of their mutual connexion with a third; and where it is not necessary to attend to this third or intermediate idea, the more the connexion between the first and second is confirmed, the less will the third be perceptible; so that when the association becomes completely fixed, the intermediate idea is often lost entirely from the view of the mind. The absence of the intermediate idea is often so complete, that its ever having been present can only be discovered by tracing the progress of the connexion between the extremes; and in certain cases, where the association has been long in a perfect state, the difficulty may become so great, that we are inclined to admit an intermediate idea, only because we perceive it in other similar cases, and perhaps in the very same connexions in other individuals whose habits are less fixed.

This is an exceedingly important and constantly operating law of association: it is thus innumerable phenomena are produced, which at first sight appear inexplicable upon any known principles, and which therefore are referred to *instinct;* that is, they are supposed to result necessarily from the conformation of the mind, without the operation of any acknowledged faculty of the mind. Such are the belief in what is called self-evident truths, the pleasures derived from objects which do not affect the mind by direct sensation, disinterested affections, &c.

We need not go far for instances which will explain the law of transference. Suppose a person acquiring another language, the French, for instance: he learns the meaning of a French word by means of a corresponding English word; by degrees, as the French word becomes familiar to him, he understands it without at all thinking of the English word. Here the signification is transferred to the French word, so that the English word is no longer wanting to form the link of union.—Those who are conversant with short-hand, can read it without thinking of the long-hand: yet they learnt it through the medium of the long-hand words.—Those who have long

learnt to read, and who have read much to themselves, often do not think of the sound of the words, when they are reading to themselves. When we are pretty familiar with a subject, a single glance of the eye over a page of a clearly printed book, will convey to us the idea of its contents, when perhaps not a single word has particularly attracted our attention, when, certainly, there has not been time for the mind to think of the sound of the words. We do not recommend this habit of reading for young persons; but simply state a fact which is very convenient and useful to the mind, when it has gone through sufficient discipline of accuracy, &c. Now it is obvious that in almost all cases, persons learn to understand printed words through the medium of spoken words.—One more instance, and we have done with mere illustration. Those who are familiar with writing, never think of the printed word, unless any particular circumstance call it to the mind. Yet there are few instances in which the written word is not connected with the spoken word by means of the before learnt printed word.

With respect to the *disinterested affections*, we shall have occasion to say more hereafter; and we shall now give a very brief outline of the progress of the *love of money*, merely as a preparatory illustration of the law of transference*.

Money is first an object of pleasurable feeling, solely as a *means* of procuring other things which are regarded as objects of desire. For a moment we may sometimes think of it, as having some intrinsic value, independently of its utility as a means; but we may satisfy ourselves that this is not the case, by observing how little money (as such) is an object of interest to children who have not heard much about it, or seen it employed, or employed it themselves. As persons advance in life, money is continually found to be the means of procuring a great number and variety of the sources of present enjoy-

* An interesting and important investigation of the origin, progress, limitations, &c. of this desire, may be seen in Hartley's Observations, vol. i. prop. 99.

ment; hence pleasurable feelings are continually connected with it, and it becomes more and more an object of desire. In this stage of the progress of the love of money, it is desired as the *means* of procuring certain pleasurable feelings, without specific reference to the objects by which those pleasurable feelings are directly produced. And even in this state of it, we find an instance of the law of transference. The pleasurable feelings resulting from the objects procured, or to be procured by money, become associated with the money itself, without reference to those objects.—This transference may, in this instance, and many others, be carried one step further. In this state, money is desired on account of the pleasurable feelings with which it is connected; but by degrees the desire is transferred from the pleasurable feelings, with which it is connected, to money itself, and money is loved *for itself*, without any reference to those pleasurable feelings. The desire of money has now reached the ultimate state of an affection: money is no longer desired as a *means*, but as an *end;* it is desired and loved *on its own account.*

IV. The influence of the associative power is not limited to those cases in which ideas are presented to the mind together, or in close connexion: by its agency an idea often suggests others, with which it has never been before connected. An object which has never before been presented to the mind, may excite numerous ideas, or trains of ideas; while another may continually occur without exciting a single idea. And the same object will affect different persons differently; so that in the mind of one it will excite trains of thought, while in another it will only produce a momentary impression; and in different persons, too, the same object will excite different trains of thought; and in the same person, at different times, different effects will be produced.

The general fact is, that when an idea is presented to the mind, either by sensation or by association, bearing certain relations, either in itself, or in its effects on the mind, to another idea already in the mind, the latter is recalled by the for-

mer, and becomes connected with it: and the association thus produced, is subject to the same laws with those formed owing to the contiguity in the times when the ideas were received.

Contiguity in time or place furnishes the grand original principle of association; next to this, the relation of similarity is the most operative. These are common to all persons, and depend but little upon the exercises of the understanding: in many cases they require to be restrained by it. The more refined principles, viz. those of contrariety, cause and effect, means and end, premises and conclusion, are the result of culture. On all these we might enlarge; but we have great pleasure in referring our readers to the elegant, interesting, and generally satisfactory investigations of Mr. Stewart, connected with this object, in the fifth chapter of his Elements.

We shall only farther observe under this head, that the connecting influence of association extends not only to our thoughts and feelings, but also to all our mental states and operations, whether they respect intellect or affection.

§ 3. *Respecting the* Composition *of Ideas.*

Another grand law, or mode of operation, of the associative power, is that by which *simple* ideas (the uncompounded relicts of sensations), are combined and blended together, so as to form *complex* or *compound ideas.*

If a sensation has frequently occurred in connexion with other sensations, (either singly or several together, either at the same instant or in succession, from the same organ of sensation, or from different organs), the former sensation, or its simple idea, will raise the corresponding simple ideas of the rest, and associate them together. If these simple ideas are distinct in all their parts, then, in the first instance, they will be merely *connected*; but if they are not thus distinct, they must more or less run into each other, so as to form a complex combination. Now the more the connected ideas occur in connexion, the more closely the single ideas become united: if no one of them have a peculiar degree of vividness, they will

by degrees, appear to the mind as *one* idea; and unless the notice of the mind is directed to the circumstance that this is composed of parts, it appears as much a single idea as originally each of the parts would have done, if the attention had been directed to them singly. And, in like manner, the more ideas of the other class occur in combination, the more completely the parts coalesce; so that by degrees they form a *complex idea*, the parts of which are scarcely distinguishable.

It may require some thought to enter fully into the above statement; but it will well repay reflection; for it affords a view of the mode in which are formed the elements of all our most refined *notions* (except the ideas of reflection), and of all our most refined *feelings*, even such as at first sight appear to have nothing whatever to do with sensation.

These elementary complex ideas do, in like manner, become connected and combined with others, and form still more complex ideas: and while these processes are going on, through the agency of association, the understanding is often directly engaged upon the elementary or the more complicated ideas; and new compounds are formed by its operations, or those already formed become modified by them. By these operations of the understanding, various principles of union and combination are brought into view, which call the associative power into action: and the system of complex ideas (both of the intellect and of feeling), becomes materially different, through these varied intellectual processes, from what it would have been by the agency of the associative power alone.

If the number of simple ideas, which compose the complex one, be very great, and they have often occurred in combination, it may happen (and in fact often does happen), that the complex idea shall not appear to bear any relation to its component parts, or to the external senses by which the original sensations were received. The reason is, that each single idea is overpowered by the sum of all the rest, as soon as they are intimately united together. It will illustrate this, if

we recollect, that in very compound medicines, the several tastes and flavours of the separate ingredients are lost and overpowered by the complex one of the mass: so that it has a taste of its own, which appears to be simple and original. Thus also *white* appears, and is vulgarly thought to be, the simplest of all colours; but it really arises from a certain mixture of the seven primary colours in their due shades and proportions.

We shall have occasion afterwards to say something respecting the mode in which what are called *abstract ideas* are formed; and we shall in this place confine ourselves to some remarks respecting the *mental feelings*, i. e. those pleasures and pains in which sensation is not immediately concerned. These Hartley calls *intellectual pleasures and pains*; we prefer the term *mental* feelings, in opposition to the mere *corporal* pleasures and pains, the pleasures and pains of sensation. The term *sensations* is too often used in reference to the *mental feelings;* but it should be strictly confined to those *feelings* (using the word in its widest sense), which are produced independently of association, by affections of the bodily organs of sense.

Now the whole system of mental pleasures and pains is formed by the agency of the associative power (under the occasional control and modification of the understanding), from relicts of the pleasures and pains of sensation. The sensible pleasures and pains leave feelings behind them, corresponding to the simple ideas of sight or hearing. These feelings (agreeably to the law stated at the beginning of this section), become associated with other feelings derived from the same, or similar external objects; and when the union has been exercised sufficiently long, they become blended together, so as to form a complex (though apparently simple) feeling, which may itself become united with other complex feelings; and so on. The greater the number and diversity of the component feelings, the more remote will the complex feeling be from resemblance to the original sensible pleasures

or pains. These complex feelings are continually receiving fresh materials, from the union and combination of the simple feelings derived immediately from sensation,—of the various complex feelings already associated with those sensations,—and of those which in different ways are called up by the various exercises of the memory, imagination, and understanding. From these sources together, the vividness of the mental pleasures and pains may, in many instances, be as great as that of the sensible pleasures and pains; and indeed we know, as a matter of fact, that the influence of the former on the mind, is often much greater than that produced by very vivid pleasures and pains of the latter class.

These views must, one would conceive, be admitted by all who have attentively considered the laws of association, and the actual processes of their own minds in the formation, or variation, of their feelings associated with any object, and the gradual formation and refinement of the feelings of children; and they lead to a variety of most important conclusions connected with education and self-culture. Some of these will be hereafter stated.

Our original bodily structure, and the impressions and associations which affect us in passing through life, are so far alike, that there must be a general resemblance among mankind in respect of the mental pleasures and pains; and yet, as there are great diversities in the causes, there must be also in the effects. Similar remarks might be made respecting that class of ideas which we term *notions.*

The sensible pleasures and pains have a greater tendency to destroy the body than the mental ones. The latter being collected from various sources, do not much injure any organ particularly, but rather bring on an equable gradual decay of the system. This, however, is upon the supposition that they are not excessive; for excessive desires or emotions, even if of a refined nature, have a direct tendency to injure the mental system generally, and especially to bring on that derange-

ment of it, which is closely allied to insanity, even if it do not bear the name.

§ 4. *On the Affections, &c.*

The limits of this work will not permit us to enter into the analysis of our mental pleasures and pains, or into any particulars respecting the different classes of our affections, &c. but the reader will find ample sources of information in the latter part of Hartley's first volume, and in Dr. Cogan's excellent works on the Passions.—To illustrate, however, the formation of the affections, we shall here give a brief history of the filial affection in its early stages: and then we shall state some of the chief principles respecting the affections and feelings in general.

1. *Of the Filial Affections.*—A child receives almost all his earliest pleasures from his parents, or in connexion with them. These all leave behind them feelings which the ever-active principle of association unites and blends together, and connects with the appearance, and idea, and name of the parents; and thus renders it pleasant to a child to see them, and to hear and think of them. By degrees he learns to distinguish them, as the cause of many things which give him pleasure: he perceives them endeavouring to do what will make him feel happy: he is the object of a thousand tender endearments and kind offices: and every thing of this description, which at all affects his mind, leaves some impression behind it, which unites and blends with the feelings before produced by other similar circumstances. Thus gradually rises up in the mind that part of the filial affection which we term *love.* If children have little intercourse with their parents, or that be little productive of pleasing feelings, their love will be weak; in other cases it often early proves very powerful.

Filial love cannot advance far, without exciting in the mind of a child the disposition to do what he finds will please his

parents. He is early incited to this by the promise of some gratification, by the expectation of some endearment, &c.; and such is the wise structure of our mental frame, that what is often done with a view to some good, gradually becomes itself pleasant, and is done without any direct view to that good. Thus a child forms a *desire to please* his parents, which constitutes another part of filial affection.

Again, in a wise education, it will often be found necessary to check the gratifications of a child, to use the language and tone of displeasure, and sometimes even to inflict pain. Every circumstance of this kind leaves behind it an impression, which, uniting and blending with others of the same kind, produces the feeling of *fear*. If this, owing to any cause, is excessive, it gives to the filial affection a character, which makes it rather the source of pain than of pleasure, and sometimes even overcomes the love. On the other hand, where it is moderate, (arising only from that degree of privation, or pain, which is necessary for the future welfare of the child), so far from lessening the happiness of the filial affection, it increases it, blending with the love, so as to lose its own painful influence; and, at the same time giving firmness and even vigour to filial love, by heightening the disposition to obedience, and thereby increasing the pleasing consequences of obedience, by heightening the fear to offend, and consequently preventing the ill consequences of disobedience.

Thus by pleasures derived from the care and tenderness of parents, and by the privations which their care and tenderness may alike cause, a vast number and variety of impressions are produced; which, all uniting and blending together, constitute the *filial affection*, consisting principally of *fear* and *love*, the *desire to please*, and the *fear to offend*. As the child advances in knowledge, and as the conscience acquires its power, the sense of obligation, the perception of the virtues of his parents, the feelings which he is led to entertain towards God, and a great variety of other sources, contribute impressions of *duty*, of *gratitude*, of *respect*, &c. towards

the general affection, uniting and blending with it, and increasing its strength and vigour; so that it often becomes a leading affection through the whole of life.

We have taken only one case, but the reader may easily pursue the same plan in other cases. Perhaps it may be truly said, that in no two instances is the filial affection in every respect the same: it is formed from impressions so numerous, so various, and often so peculiar; and depends so much upon peculiarities in the dispositions and conduct of the parent, and in the dispositions of the child.

What may with propriety be termed the *natural* affection of children towards their parents, (arising without the exercise of reflection at all, merely by the operation of the associative principle,) is almost always the strongest towards the mother; at least if she has also been the nurse: and as the pleasurable feelings of infancy do greatly contribute their share towards the formation of more complex pleasures, and as they cannot be replaced but by a long series of exertions, a mother who wishes to possess the highest degree of her children's affection, and the greatest influence in the regulation of their conduct and dispositions, must also be their nurse.

2. *General Observations respecting the Affections, &c.*

I. The affections, according to the statements already made, are derived immediately from sensible pleasures or pains received in connexion with any object, or from compound feelings already formed by association, or from both together. They depend therefore for their *formation*, upon the general activity of the associative power, upon the proper supply of materials from sensible or mental pleasures or pains in connexion with the object, upon the physical sensibility of the system, and upon the facility and vividness of the powers of recollection and conception. No affections can spring up towards any one with whom we have no intercourse, unless that deficiency is supplied by proper impressions on the mind, through the medium of the intellect.

II. The affections which have been formed towards any object, are capable, in favourable circumstances, of being transferred to another which is considered as possessing those qualities owing to which they were originally formed. And this *transference* of affections, (by which we do not of course imply the removal of them from the original object,) may take place through the medium of the intellect alone, as well as by external impressions; by the exercise of the memory, the understanding, or the imagination, as well as by actual sensation. The filial affections, for instance, may be transferred towards the Supreme Being. Where love, and gratitude, and submissiveness, have been formed to the earthly parent, they will easily be transferred to our Heavenly Father.

III. The *vigour* (including vividness and steadiness united,) of any affection, will greatly depend upon its similarity to the prevailing dispositions of the mind, and upon the frequency and continuance of its exercise, as a whole, or in some or other of its component affections.—Hence the extreme difficulty of cultivating the religious affections, when the prevailing biases and dispositions are in opposition to them; and the impossibility of acquiring piety in any tolerable vigour, without the frequent exercise of those affections which compose it.

IV. It is a principle of the most extensive application, that *feelings* become *less vivid* by repetition, while *habitual motives* become *more powerful* by exercise.

Be the *habit* what it may, the effect of custom is to increase its power. We find it to be the case in those little peculiarities of gesture, of tone, of look, which give the external characteristics to the individual; and still more so in our mental and moral processes of every kind. Its influence extends to our trains of thought respecting the past and present, to the operations of imagination respecting the future, and to our internal motives, and habitual tendencies: appetite, thought, emotion, passion, desire, affection, and action, are all subject to the same law.

With respect to *feelings*, repetition gradually lessens their vividness. This is the case, for instance, with the feelings of compassion, excited by the frequent contemplation of fictitious or even of real distress. The sensibilities which are designed to excite to benevolent exertion, and which, if thus employed, while they become less ardent, will produce more and more confirmed habits of active benevolence, if they are allowed to spend themselves in mere feelings, lose not only their vividness, but their vigour. They may continue to delude their possessors with the idea that they have really the feelings of compassion, because, from long habit, the tear starts at the tale of woe; but if compared with their former state, they would appear lifeless; and they must be pronounced worthless, because they are unproductive of any efforts, or privations, for the good of others.

It is true there are, in many instances, means of increasing the causes of feeling, where the same causes would lose their efficacy, at least their impressiveness. The pleasures derived from the discharge of duty, for instance, are all self-consistent; and they spring from such numerous and copious sources, that they increase by employment, in stability and vigour, as well as purity; but we think it cannot be denied, that even these lessen in vividness in the middle and later periods of life. Such indisputably is the general law of our frame. *Familiarity with any feeling or impression renders it less vivid.*

Connected with these remarks we must add, that *the feelings should never be excessively excited.* Repeated and strong excitement of feeling, is usually followed by inability to derive pleasure even from those external objects, which, if the mind were in its natural state, would readily yield it;—by inability to relish the common comforts of life, or to engage with satisfaction in its common duties;—and indeed, for a time at least, by inability to enjoy again those emotions which, while they lasted, seemed to raise the mind to the highest degree of felicity.

Excessive excitement of feeling, be the object what it may,

is always attended with similar effects; and those ought to be more carefully guarded against, who are most prone to it, whose feelings are lively, and whose imagination is strong. It is very apt to make the thoughts and desires centre in *personal* happiness. There is a *virtuous*, a *religious* sensibility; and where this is properly regulated, it conducts to high excellence of character: but there is also a *selfish* sensibility, acutely alive to every feeling and want which respects itself: there is a *morbid*, a *sickly* sensibility, which spends itself in feeling, which seldom produces any valuable exertions, which shrinks from self-denial and privations, which makes even benevolence itself a burden; and this is often originally produced, or greatly cultivated, by excessive excitement of feeling.

Where the sensibility is directed in a religious channel, there is often great necessity for caution. Where the feelings are not employed as the actuating motives to that regulation of the dispositions and the conduct, in which religion really consists, however much they may be made to light up the flames of enthusiastic emotion, of imaginary piety, they will by degrees lose all their real worth, acquire a merely selfish character, and at last sink into a state in which the whole power of religion will be lost. Whenever any one perceives such tendencies in his mind, since they conduct to these deplorable effects, he should be peculiarly careful to avoid the indulgence of those feelings which have no direct reference to duty and the welfare of others, and the excessive indulgence of any; to endeavour as much as possible to employ the feelings in some useful channel, and to attend to the common concerns and duties of life; and to confine himself in a great measure to those pursuits, whose direct tendency it is to strengthen and cultivate the powers of the understanding, to the partial or entire exclusion of those which enliven and excite the sensibility and the imagination.

It is of great importance to be borne in mind, in every stage of moral culture, that where any part of the system of feeling is unduly called into exercise, it increases the irritability

of the whole: that the physical powerfully acts upon the mental sensibility, and this in turn upon the physical sensibility: that whatever increases the pleasures of sensation beyond their natural state, must also increase the susceptibility of the sensible pains: and that the influence of these upon the happiness, (when they arise from, or are accompanied by, an excessive irritability of the nervous system,) far exceeds that of the sensible pleasures arising from undue excitement of body or of mind.

V. Affections (whether of love or hatred, of desire or aversion,) may be eradicated, if they have not been too long exercised, and too long associated with the general dispositions of the mind. To destroy any wrong disposition, however, will be difficult in proportion to the degree in which it has gained habitual power, and in which it is supported and cherished by other related dispositions. If the object be effected at all, it must be by perseverance in the judicious and steady culture of opposing dispositions,—in the careful avoidance of the causes of its excitement,—and in the regular restraint of its exercise by connecting it with painful feelings: and the discipline of providence sometimes effects what would not yield to any human discipline or efforts.

The *refinement* of mental pleasures or pains consists in their remoteness from sensation; the *disinterestedness* of affections, in their having no further end than their own immediate object.

VI. The *refinement* of our feelings is a very gradual process; nevertheless it cannot be doubted, that those means of intellectual and moral culture, which are supplied by the pursuits of literary, scientific, and religious knowledge, do greatly accelerate the progress of the mind towards spirituality; and this is still more effected by the gradual cultivation of the motives of benevolence, and piety, and a sense of duty. Whatever pursuit or pleasure calls off the attention of the mind from mere sensation, or the pleasures most nearly allied to it, contributes to its progressive refinement.

VII. The last of the general principles which we have to

state, respects the *disinterestedness* of the affections; and as this is a point of a highly important and extensive application, and will require some enlargement, we shall make it the subject of a separate division.

3. *Of the Disinterested Affections.*

Two opposite opinions have long been entertained, and are still often advanced, respecting the disinterestedness of the human mind. Some have maintained, that the mind, in all its feelings and promptings to action, is influenced by selfish motives; that, in fact, there is no action or feeling which can be called disinterested. Others have, with more success, maintained, that the mind can be, and often is, disinterested; that a person frequently performs an action tending to the good of others, without the remotest reference to himself, with no other motive than a desire to do the good which is the effect of the action. The degrading system of the former is seldom adopted, except by speculative men, who have been led by circumstances, happily not universal, to see merely the dark side of human nature, and to form a more gloomy picture of its selfishness than truth would allow; or by others, who have expected too much from the beautiful speculations of theory, and having been disappointed by comparing them with their own feelings in many instances, or with the general conduct of men, have thence gone to the unfounded opinion, that all the actions of all men are selfish. But many of those who are undoubtedly right in the pleasing belief that the affections and motives of men are often characterized by disinterestedness, have greatly erred respecting the nature of it. From attending to its state in their own minds, or the minds of others, where it is habitual and extensive, and forgetting the stages which have led them to this noble eminence, they have supposed disinterestedness to be an innate principle of the mind, and the first step towards true worth of character, whereas it is in reality the last. They have, therefore, decked the commencement of virtue in colours which belong only to

its completion: and hence two practical ill consequences have followed; some persons have neglected the culture of disinterestedness, both in their own minds and in those of others, from supposing it to be a necessary quality of all virtuous affections; and others have been driven to despair, on comparing the picture of theory with the faulty state of their own minds, supposing that they could never attain to what they see represented as alone entitled to the appellation of virtue.

The more correct views, surely, are, that disinterestedness is the last stage of an affection; that it may be hastened by attention to the culture of the affection, or retarded by the neglect of it; and that disinterestedness, as the general character of the mind, is the highest point of excellence, and what should be our object, but can only be acquired by a long course of religious culture.

When explaining the *law of transference*, we shewed how it operates *to change means into ends*, and causing that which was at first an object of love and desire, *as a means*, to be loved and pursued *on its own account*. It may be useful to apply this principle to the formation of *disinterested benevolence*.

Every human being receives his first pleasurable impressions in society. His appetites are gratified by the assistance of those around him; and probably there is no agreeable feeling which is not, in some way or other, associated with those who attend him in the period of infancy and early childhood. Hence arises *sociality*, or the pleasure derived from the mere company of others; and, as the child increases in years, the associated pleasure increases almost continually. In the innocent and generally happy period of childhood, he receives all his enjoyments in the company of others; most of his sports and amusements require a playfellow; and if by any untoward circumstances he is prevented from joining his companions, he feels an uneasiness which it is scarcely in his own power to remove, but which vanishes as soon as he can rejoin them.—But his happiness derived from others, depends greatly upon

the happiness of others. He is happiest when those around him are happy; partly from the contagion of feeling, and partly because his means of happiness considerably depend upon the convenience of others. If his companions are ill, his sources of pleasure are diminished: if his parents are unable to take their customary care of him, he misses it in various ways; he loses the caress of affection, or the little kindnesses of parental tenderness. Hence the comfort and happiness of others necessarily become the object of desire; and even in young children, it not unfrequently happens that this desire becomes sufficiently disinterested, to lead them to forego small pleasures, or endure small pains, in order to increase the comfort of their parents, or to prevent what would diminish it.

Benevolence is that affection which leads us to promote the welfare of others to the best of our power; and general benevolence is founded upon particular benevolence; for instance, upon affection to parents, or other near connexions. We have seen its rudiments, and it may be well to pursue it further.— The endeavour to promote the comfort or welfare of others, is, in the early part of life, almost invariably followed with an increase of pleasurable feelings. Parents approve these endeavours, and tell their children that God approves of those who try to do good to others. Children and young persons are continually feeling and observing the good effects of benevolence, as manifested in their own conduct, or in that of others; and hence, in well-disposed children, the pleasurable feelings associated with benevolent actions, are very strong: they are very glad to see others made happy, and very glad to be enabled to make others happy: and the pleasure derived from the approbation of others, and the approbation of their own minds, the increase of good-will in the person benefited, and the expression of it, the accordance with all the religious feelings which are possessed, and various other circumstances less general, associate, together, such a stock of pleasurable feelings with the doing of good to others, that by degrees, in some

or other of its branches, it is an object of desire altogether independently of any consideration beyond itself.

A person who has completely gone through this process, desires to benefit others, without any reference to his own personal benefit, in this world or even in the next: he employs the different opportunities which present themselves to him of doing good to others, without thinking of any thing more than the immediate object. If it call for great exertion on his part, or great efforts of self-denial, he brings to his aid the desire of following the dictates of duty, or of obeying the commands of God; and where his benevolence, his love of duty, and his love of God, are in a great degree purified from self, (and in proportion to such purification,) he will forego great pleasures, and endure great pains, without a thought beyond the production of the good which he has in view, and obedience to God and conscience. Such heights of excellence are seldom attained without a large proportion of the discipline of trial and affliction; and they imply the suitable improvement of it: but a less and not despicable height is often observed.

There are few points in moral investigation more interesting, or of greater practical value, than the tendency to love, and to desire to promote, objects which have no immediate connexion with our own good, without any reference to our own good. That the human mind is capable of gross selfishness, which defies all present discipline to correct, is a fact which cannot be denied, and which should excite our vigilance and concern. But it is no less a fact, that it is also capable of disinterestedness, which shall run through the whole of the conduct, and prompt uniformly and steadily to the promotion of others' welfare. The earliest pleasures are *personal;* we would not call them *selfish,* because the term is appropriated to those feelings which have an *explicit* reference to our own real or imaginary good, and which prompt to this even at the expense of others. In this sense the human mind cannot with the least propriety be said to be originally selfish; but its earliest pleasures are personal, and its earliest desires

are consequently personal. Its interest in the pleasures of others, arises originally from the connexion of them with the personal pleasures; and, consequently, the love of others, and the desire of benefiting them, are originally interested; that is, they arise from the dependence of its own personal pleasures on their pleasures. There is nothing criminal in all this; it is according to the laws of our mental frame: the mind is criminal only when it rests here, for it cannot without being wrongfully impeded. If the progress go on as it ought, the desire will be gradually transferred from the original end, personal pleasures, to the *good of others,* the *original means*; and *this* then becomes the *end,* and the desire is disinterested.

We may then, with the consistency of truth, indulge a delightful view of the tendencies and capacity of our nature; and hold up as the object of our steady exertions after moral improvement, that state of mind, in which to perceive a practicable means of promoting the good of others, and to employ it, will be invariably connected, without any intervening bond of union, without any other motive co-operating, but what is as pure as its own benevolence.

Similar remarks might with equal truth be made respecting religious obedience, and a sense of duty; but we must leave this application of the foregoing principles to the intelligent reader. It may, however, be well to observe, that the cultivation of the religious affections, and of an habitual sense of religious duty, has a most beneficial effect in elevating the mind towards general disinterestedness. The hopes and fears of religion, have themselves a purifying influence; and no motive can have a more direct and powerful tendency, (proportioned to its own strength and consistency,) in giving firmness and purity to the moral principle, than an habitual regard to the will of an omnipresent being, and an habitual desire of his approbation.

No one can, with justice, think less highly of the promptings of disinterestedness, because it can be shewn to arise from

a meaner origin. Ought we not rather to admire the height which has been gained by a steady use of the general means of worth, and by a right employment of the discipline of Providence? Is his conduct less lovely, who has gone through the trial, and brought from it disinterestedness, which prompts to efforts of the noblest kind for the good of others?—The opinion that the mind is *originally* disinterested, may in some points of view be pleasing; but in others it is the contrary: it diminishes the value of the character where it exists, for constitutional disinterestedness could have no more merit than the possession of a good sight; and it damps too the efforts of the mind to obtain disinterestedness. Those who find themselves deficient, who discover feelings which disinterestedness cannot approve, have, on the principles which we have been aiming to illustrate, the best encouragement in their endeavours to transfer their affections from self. These principles lead too, humbly and gratefully to acquiesce in every means which Providence may appoint, to discipline the mind, and to purify it from all that can debase. In short, they point the view to the highest excellence, and direct to the means of attaining it.

CHAP. XIV.

UNDERSTANDING.

Source of error respecting its operations—Consciousness—Attention—Observation—Reflection—Thinking—Meditation—Habit of Abstraction—Power of Abstraction—Words—General notions of sensible objects—Affections associated with words—Words denoting objects not sensible—Import of words often gained indirectly—Words often substitutes for other words—Judgment—Reasoning—Investigation.

THE term *Understanding*, in its most extensive application, clearly includes all our intellectual operations; but we here use it in the narrower sense already stated, to denote that power of the mind, by which it contemplates ideas and sensations (considered as such) and its own various operations; by which it discerns the relations that exist among the objects of perception and thought; pursues truth; and assents to propositions, or dissents from them.

The discussion of this faculty involves the most difficult and intricate questions in mental philosophy; and all that we can attempt is, to give such elementary ideas as may put our young readers into a proper track for investigating the subject for themselves. The operations of the understanding have so extensive a range, and such a variety of objects, and it is so difficult, in many cases, to ascertain their precise nature, that there is abundant room for the exercise of this power, during the whole of life, in the examination of its own processes.

Much has been written on the subject; and from different writers, many valuable hints may be derived; but almost all have erred in considering those processes in too limited a point of view. In the second volume of Mr. Stewart's Elements, that philosopher justly attributes some of the errors into which his predecessors have fallen, to their considering the intellectual processes employed in mathematical demonstration, as exactly similar to the acts of reasoning and judging on other subjects; and it appears that he has fallen into the same error, in his remarks connected with abstract or general reasoning. Indeed, when reading Mr. Stewart's highly valuable and interesting works on Mental Philosophy, it is necessary to remember that he has not embraced the theory of association in that extent, which alone could enable him to see the real nature of the proceedings of the understanding in various cases where the operations of the mind, and the operations of language are connected together.

In our brief view of this faculty, we shall offer a few remarks under the head of Consciousness, Attention, Observation, Reflection, Thinking, and Meditation,—Abstraction,—Words,—Judgment, Reasoning, and Investigation.

Consciousness is that property of the mind, by which it is capable of being affected by the mental changes accompanying sensations and ideas. It is in fact, the notice of the mind itself; and the term is, in the most appropriate sense, applied to that state with which every mental change or operation is attended, provided it in any degree excite the notice of the mind. It is by consciousness alone, that we have any knowledge of the other powers of the mind; and when directed to their operations, the appellation is peculiarly appropriate. When it is excited by sensible changes, it is usually called *perception*: consciousness referring to the operations of the mind as such; perception to them as produced by external objects. We are *conscious* of ideas and sensations; we *perceive* the external objects which produce impressions on the senses.

When the notice of the mind is continued to any particular

object, or succession of objects, whether or not that continuance is caused by volition, the state of mind is called Attention. When it is brought so far under the power of the mind, that it can be produced by direct volition, then it is with propriety termed the *Power of Attention.*

We have no doubt that many corporal, and even mental operations, may, when thoroughly habitual, go on without exciting the attention of the mind: but without entering here into that difficult question, we may state, as more important, that before any operation of the mind is become habitual, the exercise of it requires the direct notice of the mind;—that attention is requisite to render sensations efficacious;—that every exercise of the understanding requires it;—and that the habitual power of employing it, in the direction which the judgment points out, may be regarded as what is most necessary for the attainment of the highest degrees of intellectual culture. In this perfect state, it is very rarely to be met with; but in a considerable degree it is frequently acquired; and some good portion of it is so important in every stage of the mental progress, that the formation of the habit cannot be too early begun, nor the cultivation of it made too steady an object.

When the attention is directed to external objects, it is called Observation. The term is one of such familiar, and generally appropriate use, that it can scarcely be misunderstood: it is applied to the attention, solely as directed to the present objects of perception, leading to thought respecting them.

To observe with effect, requires patient and frequently repeated attention. To observe is not merely to see; but to see so as to perceive *that*, whatever it be, of which the ever active principle of association has made the visual sensation the symbol, or index; and the more the observation is well employed, the more will be brought into the view of the mind by sensations, which to another would not conduct one link in the chain of thought.

The habit of observation depends in part upon the general

culture of the mind, especially upon the associated thoughts and feelings connected with external objects. The poor plough-boy, with all the advantages that his rustic employments afford him for the excitement of his observation, will often be found extremely deficient in that habit; his perceptions are dull, and his mind is scarcely awakened. Sensations often repeated, without any associations being formed with them, cease to excite the notice of the mind; and where the work of instruction has been totally neglected, (as unhappily it so often is among the poor in country situations,) the noble powers of the mind lie dormant: there is nothing to rouse its capabilities, separate from the narrow round of the daily employments: these soon become mechanical, and cease to excite its exertion: and as far as intellect is concerned, the situation of the labourer is surely less favourable than that of the untutored savage, whose ingenuity and observation are stimulated by the necessities of life.

The habit of observation is of essential value in every branch of education, and in every department of life. The successful acquisition of every science depending upon experiment, indeed the acquisition of knowledge of every kind, which depends upon the exercise of the perceptive power,—the cultivation of the taste,—the common concerns of life,—the intercourses of civility,—and the efforts of benevolence, require the constant exercise of the observation. By a proper cultivation of it, the memory and judgment are directly cultivated; and while it strengthens and rouses the energy of the mind, it furnishes it with some of the most serviceable materials for the understanding and the imagination.

When the attention of the mind is directed to its own states, affections, and operations, it is termed REFLECTION. As observation commonly implies some exercise of the reasoning faculty, so also does reflection; but simple attention to our own thoughts and feelings, and to our manner of thinking and feeling, is in the strictest sense *reflection*. The term is however used in common language much more extensively, to denote the *attentive consideration* of any subject of *thought*.

When the mind is employed in the consideration of any ob-

ject of thought, it is said to be THINKING. In a wide sense, this term includes every intellectual operation; in other words, it includes whatever may be called an act of the understanding, that is, every act of the mind properly so called, except sensation and feeling. But it appears most appropriate to that state in which the mind is actively employed in the consideration of thought, whether of its perceptions, notions, or feelings. The term *thought* has two significations, the *act* of thinking and the *subject* of thinking. Considered as denoting the subject of thinking, it nearly corresponds with *idea, notion, opinion,* &c.

When the mind is left in its trains of thought very much to the operation of the associative power, without any direct restraint upon it, from without or within, its state is termed MEDITATION; which bears nearly the same relation to the understanding, that *reverie* does to the imagination. The term is however used where the mind is more actively engaged, particularly on serious subjects of thought. It does not very greatly differ in its import from *comtemplation,* but this term often appears more particularly to refer to the fields of *observation,* rather than of *reflection.*

Of the Habit of ABSTRACTION. When the attention is directed to some particular object of thought, so as to prevent its being diverted to any other object of thought, or to any external impression, it is denominated *Abstraction.* This state of mind has seldom been dignified with the name of abstraction, except when directed to objects out of the common sphere of thought; but Miss Edgeworth has shewn, by her usual happy method of illustration, that it is the same habit or exercise of mind, whether it be devoted to the highest flights of philosophic pursuit, or to the usual concerns of life. "Persons of ordinary abilities," she justly remarks, "tradesmen and shopkeepers, in the midst of the tumult of a public city, in the noise of rumbling carts and rattling carriages, amidst the voice of a multitude of people talking upon various subjects, amidst the provoking interruptions of continual

questions and answers, and in the broad glare of a hot sun, can command and abstract their attention, so far as to calculate yards, ells, and nails, to cast up long sums in addition right to a farthing, and to make multifarious bills with quick and unerring precision."

The habit of abstraction is dependent upon various causes; but every person to whom the attainment of it is necessary, finds it susceptible of culture. It much depends upon the familiarity of the impressions which are otherwise most likely to affect the mind. Novel impressions from external objects, by their novelty, attract the notice of the mind, and tend to distract the attention. Sensations which have been long and closely connected with trains of thought or feeling, are calculated to divert the attention. Objects to which we have been accustomed to attend, in like manner solicit the notice of the mind from those to which we may otherwise wish to attend. In situations, therefore, where we receive novel sensations, unless there is a proportionate devotement of the mind to the object of its attention, these will at first distract the attention; and so on in other cases. Abstraction depends too, in part, upon the physical state of the system. If the nervous system is in a strong degree of excitement, external impressions proportionally affect the mind, and, of course, tend the more to distract the attention. Abstraction is likewise seriously impaired, by a general tendency to dwell upon the directly selfish feelings, whether pleasurable or painful; for (since these are constantly present to the mind, and constitute the most powerful agents, in their immediate effects upon the mental system), the habitual tendency to give attention to them, puts an almost total stop to any valuable degree of abstraction in favour of those objects which are not immediately connected with self.

The power of directing the mind to objects which afford no impression upon the senses, and even in opposition to those which do, is of extreme importance in the later periods of mental culture. Carried to an undue extent, this habit is unsuitable

to our situation as social beings: but there is scarcely any plan of life in which it is not in some measure requisite; and in the pursuits of science, whether physical or mental, it is continually required, and continually strengthened by exercise. It is even very important in the events of life. It constitutes the leading feature of that quality which we call *presence of mind,* and which is so often of signal service to our welfare, and even to the preservation of our lives. And this habit is essentially requisite in our moral and religious culture. The acquisition of religious knowledge constantly implies the employment of abstraction: in the exercise of religious affections it is absolutely necessary; and in the discharge of duty, in opposition to strong temptations, the power of fixing the attention upon those views and principles which ought to guide us, is of the utmost importance.

Of the Power of ABSTRACTION. The word *Abstraction* is also used to denote the *power* which the understanding is supposed to have, of separating the combinations which are presented to it. In many cases, however, the understanding has no such power; it is impossible, for instance, to form a conception of *extension,* without some idea of *colour,* or of *length* without *breadth.* But *the abstractive power* is, after all, nothing more or less than the power of *separate attention,* the power of attending to one idea distinct from the combination in which it occurs,—of attending to one part of a conception distinct from the rest, and perhaps by degrees, of forming a conception of that part detached from the rest,—of attending to one quality or circumstance separate from other qualities or circumstances with which it is connected in nature, or in the mind. This power is necessary in almost every process of reasoning, and it is the foundation of an accurate discriminating judgment.

The involuntary exercise of the power of abstraction, is very often produced by the mere influence of association, or without any voluntary effort; and sometimes by the influence of

the sensations themselves. But the exercise of it is often, in a great measure, voluntary; and though that degree of this power, which shall completely separate at once the combinations which are presented to it, is probably altogether chimerical, yet we may acquire it to such a degree, that the objects which we wish to exclude from the attention, shall not affect our reasonings, and but little even our feelings.

The abstractive power is brought continually into exercise in all the leading objects of intellectual occupation; and hence one advantage of the pursuits of literature, and still more of those of science. And it is of the utmost consequence to habituate the mind to separate the combinations presented to it, in order that those hasty, casual, and erroneous associations may be weakened, which so often completely mislead the judgment; and which, where they do not directly and obviously affect it, imperceptibly warp it, and materially increase the difficulties which obstruct the reception of truth.

Words.

The philosophy of language presents a wide field of investigation to the mental philosopher; and it is impossible to advance a step, without perceiving the operation of the associative power. Indeed it is solely owing to this principle, that words and phrases excite ideas in our mind; and articulate sounds and their visible representations, are, by their variety, number, and ready use, peculiarly fitted to denote and suggest by association, both our simple ideas, and our complex notions and feelings, formed from them.

Mr. Stewart has more than once said, that "many authors have spoken of the wonderful mechanism of speech, but none has hitherto attended to the far more wonderful mechanism which it puts into action behind the scenes." In Hartley's Observations, however (prop. 79, 80), our readers will find many important illustrations of the processes of the mind in connexion with language; and though they may be considered only as a basis for investigation, it is one on which we may

build with the utmost security, because it is itself founded upon the established principles of human nature. They will also be found, divested of some of the peculiarities of Hartley's phraseology, in Dr. Rees's Cyclopedia, PHILOSOPHY *Mental*, VIII. 3.—To these sources we must refer our readers for further information.

It is so obvious that the names of particular sensible objects, qualities, or actions, are connected by association, with the things denoted by them, and with the corresponding ideas, that we need not enter at all into this part of the subject. But in a variety of cases, words do not stand for an individual alone, but for any individual of the same class; not for a quality as seen always in connexion with the same qualities, but for the quality itself in whatever connexion it is presented to the mind.—Now by the well-known law of association, if the same word is applied to a number of objects, it will become connected with all the simple ideas derived from those objects: these ideas become blended together, and form one complex notion, with which the word is connected, and which it may excite. In this complex notion, the idea of those parts or properties which the objects all have in common, must be most impressive and vivid; and to this accordingly the attention is most directed, when the complex notion is suggested to the mind. Every impression that is made upon the senses by the objects to which the word *tree* (for instance) is applied, leaves some elementary ideas associated with it; and these, being combined together, form the complex notion which we perceive in the mind, when we hear or see the word. If we dwell at all upon it, we usually perceive the particular idea, or conception, of some one object of the class; some one to which we have paid peculiar attention, or which is peculiarly familiar to the mind: but when the word *tree* is used without our dwelling upon, or particularly attending to, the idea connected with it, we find it excite in the mind a faint notion, the parts of which are in no way distinguishable. This is not a *conception*, or (as we may term it, by way of illustration,) a

picture of any tree; but a complex notion, derived from a variety of impressions made on the mind by the objects termed trees. The *complex notion* (which is usually faint from its extreme familiarity), and the *conception* of an individual object, are two distinct ideas. They may be perceived separately from each other; but the complex notion connected with the appellative or general term, will usually be found, if the mind dwell at all upon it, to excite a conception of an individual to which that term is applicable. Thus the words *house, shop, tree,* &c. have undoubtedly faint complex notions connected with them: without any *conception* of an individual house, shop, tree, &c. we perceive at once a different feeling in the mind when each is pronounced, altogether independent of the difference in the sound; but if the import of the terms becomes the object of particular attention, we can scarcely avoid picturing to the mind an individual house, shop, or tree, that is, forming a conception of it.

This we believe to be a correct account of the nature of general ideas, respecting which so much dispute has arisen among philosophers; and it is obvious that it can only be explained by the agency of association. Some have supposed that we have no idea connected with a general term, except the conception of an individual to which the term is applicable; and others appear to have imagined that we can form a conception (of a triangle, for instance), which shall have none of the peculiarities of individuals. The last is manifestly impossible, for a conception must from its very nature be the idea of an individual: that the other is not the fact, may, we think, be left to the plain sense of any one capable of reflection on what passes within him. When we use the appellative *bird*, we certainly have a different *feeling* (to use the term in its widest sense) from what is excited by the word *fish;* and this before we form a *conception* of any *individual* bird or fish. And this feeling can be nothing else than the complex notion formed from the relicts of all the impressions made on the mind in connexion with the word *bird* or *fish.*

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When we are reasoning respecting classes of sensible objects, or using words denoting them, we may perceive that the words sometimes pass with very faint notions; at other times they excite a conception of some one of the class, but with the generic qualities most vivid, and the others producing only a slight impression; and at others again, the conception of an individual may be distinctly perceived. The last is most commonly the case, where the conception is one easily formed; where any circumstances have led to recur often to an individual; and where the characteristic properties of the class are striking, and do not present themselves with any remarkable diversities in the impressions made by individual objects. It is almost impossible to reason about *circles* without having at least a faint conception of a circle in the mind; but when we speak of *insect*, we can easily perceive the complex notion, without the conception of any particular insect.—It is probably in a great measure owing to the readiness with which we form distinct conceptions of geometrical figures, that some philosophers have been misled as to the nature of what are termed abstract or general ideas.

But beside the intellectual *notions* derived at once from the impressions produced by sensible objects, they often raise, by association, numerous feelings in the mind connected with the *affections;* and these are also raised up by the word through the influence of association. So that the term will not only become connected with the *idea* directly derived through the sight, or any other sense, but with all those feelings and notions which, through any circumstances, have been associated with the object denoted by the term. Thus the words *my father*, not only raise in the mind a conception of the visible appearance, but a complex feeling derived from all the feelings which have been directly or indirectly associated with that parent: and the very term will in one be attended with a glow of pleasurable feeling, which another may in no way experience. The vividness of the associated feeling in such cases depends upon various circumstances; and the variety of them

in different individuals, furnishes some of the most interesting illustrations of the power of association. In some states of the mind, those words will barely raise a faint complex notion of the objects denoted by them, which at other times would excite pleasurable feelings amounting to emotion; and similar differences may be observed in different individuals at the same time.

There is no room to doubt that the same processes take place with respect to the words which denote properties not the direct objects of sensation. Whenever the circumstances or properties which a term denotes, produce impressions in the mind, the ideas of these are associated with it; and as the term in some measure recalls them every time it is thoughtfully employed, these ideas become blended together, so as to form a complex notion, which is faintly or strongly excited by the term, according to the degree of attention which we give to it. Thus the word *right* is, from a very early period, associated with a variety of impressions, which all furnish some of the component parts of the very complex feeling connected with the term. We may not be able to define it; we may not be able even to say why we apply it to any action or quality: but whether our application is exactly just or otherwise, we have associated with the word a complex feeling of which we can scarcely fail to be conscious, whenever the word is used with any degree of attention. We call it with less difficulty a complex *feeling*, because it is a term in which the *affections* are quite as much concerned as the *intellect;* but those who are accustomed to view *right* as an object of the *understanding* merely, will have less of feeling associated with the word than those who think of it also in connexion with the affections.

The greater the diversity of circumstances in which an intellectual term is employed, (unless the features of resemblance are very striking,) the more difficult it is to analyse the notion which it suggests. We may get a *criterion* for the proper application of the term; in other words, a definition: but that

definition will seldom come up to the complex notion or feeling associated with it. For instance, we may say, that *right* denotes *the conformity of actions to a rule of duty;* but there can be little doubt that this does by no means convey the whole of the complex idea of *right,* as it is found in any cultivated mind.

Words denoting qualities not sensible, may frequently excite faint conceptions of sensible circumstances with which they have been associated, and from which they have derived part of their component ideas. For instance, after reading of some remarkable act of justice, and picturing the circumstances to our minds, we may, for some time after, have a faint conception of those circumstances excited by the word *justice,* especially if it be the object of thoughtful attention. But altogether independently of any sensible impressions of that nature, words denoting qualities not sensible, do indisputably raise up in the mind complex notions or feelings, even when used alone. We cannot doubt, that all persons have a different feeling in the mind, when they read or hear the word *shame,* from that which *virtue* excites, without their stopping to think of any particular act of virtue, or of any instance in which the feeling of shame has been produced: and altogether independently of the mere sensible difference of the two words.

We dwell the longer on this point, because mistakes respecting it are very prevalent, owing in a great measure to the authority of a philosopher, whose writings cannot fail in many parts to delight and instruct all who have culture of mind enough to understand them. If what is stated at the close of the last paragraph be the fact, and we cannot doubt it, he is altogether in an error with respect to the ideas connected with general terms. In these investigations we naturally begin with terms denoting classes of *sensible* objects; and there, as we have already observed, *conceptions* are continually interfering. But with terms denoting properties or circumstances *remote* from these sensations, we often have no conceptions associated; they raise none in the mind, except in

peculiar cases: and yet when we pronounce, or hear, or see the words, we have a complex notion or feeling in the mind, altogether different from that excited by other words whose import is different.

But words gain associations in our minds independently of the actual impressions derived from the qualities or circumstances which they denote. We learn the import of many by impressions produced through the use of them by others. Every instance in which the general import of a sentence is understood, leaves some impression with respect to any word in it, whose force was not previously understood; and the ideas derived from these, (undergoing various changes, corrections, and additions,) by degrees form a complex notion, which at least corresponds in a sufficient degree with that associated with the word by others. In this way we associate ideas with such abstract words as *existence*, *identity*, &c. And in a similar manner we acquire the proper use of many of those words called *particles*, which of themselves have little or no import, but contribute to the precision of language, by enabling it to convey better the niceties of thought.

One other class of words we must briefly notice, consisting of terms occurring in all branches of knowledge, as well as in common life, which are merely compendious substitutes for other words. Such, for instance, is the term *astronomy*; which denotes the science that explains the phenomena of the heavenly bodies. This class is very extensive: such words sometimes suggest the words of the definition; sometimes the notion, which the definition, taken as a whole, conveys; and sometimes, particular species comprehended in the general term. Thus, suppose a person to have met for the first time with the term *virtue*, and to have found that it denoted *the conformity of actions or dispositions to the will of God*; whatever idea this phrase conveyed to the mind, (either from its component parts, or as a whole,) the term *virtue* would by degrees convey: and sometimes, when using the term, he would think of the words of the definition, sometimes of their general import,

and sometimes again of particular classes of virtues, such as *truth, justice*, &c. or of striking circumstances coming under the head of virtue. By degrees however his complex notion associated with the term, would consist of ideas derived from all the cases in which it had been attentively employed.

We have here been endeavouring to give some notion of the true theory of words. Abundantly more might be said, but we shall be satisfied if we have said enough to set our readers to think for themselves; only requesting them to observe, when they are endeavouring to detect the processes of thought, that too earnest attention to these processes often carries them on beyond the point at which we wish to consider them, or altogether changes the current of thought.—Under the head of Logic, we shall have to make a few other remarks connected with the subject: and shall here only observe further, in the words of Hartley, as a general and most important conclusion, that "since words thus collect ideas from various quarters, unite them together, and transfer them both upon other words and upon foreign objects" (objects having no sensible connexion with those ideas,) "it is evident that the use of words adds much to the number and complexity of our ideas" (both notions and feelings), "and is the principal means by which we make intellectual and moral improvement."

Judgment, Reasoning, Investigation.

The characteristic faculty or capacity of the understanding, is the power of *comparing* the different objects of thought, and *discerning* the various *relations* which exist among them; such are those of identity, similarity, equality, proximity, continuity in time and place, difference, dissimilarity, cause and effect, &c. The receiving of a sensation, and the recurrence of an idea, even when these are made the objects of an attentive consideration, do not necessarily involve in them any comparison with another: and *Comparison* is therefore to be regarded as a distinct act of the mind. The paper we are writing upon is rectangular; and if we form a conception of

it, we have the same appearance as the original sensation presented: but the mind cannot, with any degree of propriety, be said to *judge*, when it merely forms that conception, or receives the corresponding sensation. As soon as our attention is directed to the form of the paper, and by comparing it with the idea annexed to the word *rectangular*, we perceive the agreement of the form with the import of the term, we form a judgment, and the operation of the mind is well called *judging*.

It was some years ago proposed by the present highly respectable Professor of moral philosophy at Glasgow, to give the appellation *Intellectual Perception* to that power of the mind, by which we *perceive relations* subsisting among the various objects of thought. This power may be comprehended under the more general head of *Judgment*, under which we may include three operations of the mind: 1st, the attention to different objects of thought, considered as different, with a view to ascertain their mutual relations or connexions; which is appropriately termed *comparison*: 2dly, the discerning of the relation which is the object of the mind, which is an operation of the *intellectual perception*: and 3dly, the consequent association of the ideas, as bearing the observed relation, which is, in the narrowest sense, the *judgment*. The first may be to a certain degree voluntary: the second depends upon the culture, extent, acuteness of the *discernment*, or intellectual perception, and cannot be said to be voluntary, any more than our sensations are: the last is a process which, like every other case of association, may be made more efficacious and permanent by voluntary effort, by directing the attention to it, &c.; but it is not in itself a voluntary operation.

The judgment clothed in words, is called a *proposition*. Every proposition expresses a connexion existing in the mind of the speaker, between the ideas denoted by the terms of the proposition, as bearing to each other the relation declared by the proposition; but it is, we apprehend, no uncommon error,

to suppose that every proposition expresses a judgment arising from a direct act of judging. Passing by those numerous cases in which the act of judging has one taken place, but is no longer necessary, there is a variety of others continually occurring, where the proposition expresses no more than that the idea denoted by the predicate makes part of the complex idea of the subject, either universally, or at that particular time. *Milk is white*, is a proposition; but if we suppose a person, who has often seen milk, to state it for the first time, we apprehend no mental process takes place to which we can justly give the appellation of judging. There is no comparison, discerning, considering, and deciding as to the coincidence of the ideas denoted by *milk* and *white:* he merely expresses a simple fact: if he has the substance before him, he tells you what he sees; if he think of it, (forms a conception of it,) he tells you what he recollects.

A proposition which is merely the statement of a connexion in the mind of the *speaker*, in no way the result of consideration, but necessarily arising from the operation of sensation and association, (without the intervention of the understanding, properly so called,) may occasion in the *hearer's* mind a real judgment, and may even require it, before the truth of it can be admitted. The proposition may be merely the statement of a complex thought; but as the terms of it represent that thought in certain parts, and in succession, if the complex thought be not itself familiar to the mind of the hearer, so as to be excited at once by the proposition, he is set by it to compare, to discern, and to decide; in other words, to judge.

In a popular sense, the term *judgment* is used more extensively, than in the philosophical acceptation (as referring to a particular power or act of the mind) it can be well employed. It is often used with as much latitude as *understanding*. We speak of the solidity, the clearness, the accuracy, &c. of the judgment, or of the understanding, with little or no discrimination; but it will probably be found that the two words are often distinguished, just as the words *understand* and *judge*.

The term *understanding* conveys less the idea of activity than the *judgment*; and refers more to the perception of truth, than to the formation of right notions. We might even say, that a good understanding and sound judgment are not inseparably connected.—In the wide sense of the term judgment, it is applicable to every act of the mind, by which an opinion is formed; and consequently includes not only judgment, strictly so called, but extends to the whole round of associations which respect the objects of the understanding. Still, even there, the communication of the judgment by language, and the judgment itself, are two distinct operations of the mind; and should in all cases be kept distinct by the mental philosopher.

The foundation of an accurate discriminating judgment can only be laid in the acquisition of clear perceptions. Where this is properly attended to in early education, the developement of the understanding will usually go on with success; where this has been neglected, the injurious effects are seldom completely remedied. *Discrimination* of judgment is a quality than which no one is more essential in the pursuit of truth: the ready perception of resemblances among diversities, and still more the quick and accurate perception of diversities in the midst of resemblances, constitute some of the most important operations of the understanding. The habit of accurate discrimination should be kept in view, and exercised in every period of education. It is indeed the foundation of clear ideas; and the acquisition of whatever can be truly called knowledge, depends most materially on the possession of it. It is exercised by various objects of instruction; and in fact it is often this exercise which gives those objects their leading value.

The operations of the understanding which are denominated *Reasoning*, are clearly of the same nature with judgment. Reasoning is expanded judging; and judging is compressed reasoning. Where the relation or connexion subsising between two objects of thought, is shewn by considering their mutual relation or connexion with one or more others, there is an

act of reasoning; and the term is strictly applicable, where one truth is inferred from another. In a variety of instances it is difficult to say, whether a judgment is formed by any process of reasoning, or simply by intuition; but it is clear, that a variety of truths, which are intuitively evident to the cultivated mind, require distinct processes of judging in others. And on the other hand, that truths appear intuitively evident, which have in reality been the subject of previous examination, but by familiarity are become so associated with the feeling of belief, that it is difficult to suppose they have ever been otherwise.

We shall here notice one other class of the operations of the understanding, which may with propriety be called *Investigation*, that by which the truth is perceived and discovered. The exercises of the understanding, when in the pursuit of truth, continually involve operations of reasoning; they depend most closely upon the discrimination of the judgment; they imply what indeed this state always implies, the exercise of abstraction; and yet there is something necessary beyond all this. It consists in tracing out the proofs on which any position depends; in determining their respective weight as evidence; in discovering the general principles agreeably to which particular phenomena have been produced, or the causes operating to produce any known effect, and their respective influence. Mr. Stewart (Outlines, p. 58.) gives the denomination *invention* to these procedures of the understanding. "The process of the mind," he says, "in discovering media of proof for establishing the truth of doubtful propositions, and also the process by which we bring new truths to light, is properly called invention." We prefer our own appellation, because it is a less suspicious one. The term *invention* seems misapplied in reference to the discovery of *truth*; though we willingly admit, that in various processes of investigation, the invention is frequently exercised.—We do not recollect, that this philosopher has furnished, in his writings, any clue to these processes of the understanding; and

we are inclined to think, that no one has thrown so much light upon the actual procedures of the mind in the discovery or ascertainment of truth, as Hartley has in his seventy-sixth, seventy-seventh, and seventy-eighth propositions, particularly in the second of these. It contains a fund of profound and important observations, the value of which cannot be affected by their having among them a few opinions, which must be regarded as mere speculations; they are the speculations of a master mind, intent upon inquiries of an interesting nature, and contemplating with pleasure, whatever appeared important for the attainment of that which indisputably was with him the first object,—TRUTH.

CHAP. XV.

THE WILL.—DIRECTIONS TO THE STUDENT.

Nature of the Will—Motives—Intentions—Habit—Mental and Bodily Habits—Moral Habits.—Directions to the Student.

THE WILL is that state of mind which is immediately previous to, and occasions, those express acts of memory, imagination, judgment, and bodily motion, which are termed *voluntary*. The will assumes different features, according to the nature of the motives influencing it: sometimes it is a simple determination of the understanding; at others, it is called into exercise by the affections, passions, &c. The causes influencing the will, with the variations in their influence, the connexion of it with action, mental or corporal, its influence over the trains of thought and feeling, &c., open a wide field for investigation, equally important and instructive; but we can do no more than point it out to those of our readers whose minds have a philosophical bent.

The extent of this work will not permit us to enter, as we should wish, into the consideration of this power of the mind; but we refer our readers with great satisfaction to the very valuable Essay of Dr. Reid on the Will, the second in the volume on the Active Powers of Man. Mixed with several positions, (particularly in respect to instinct,) in which we cannot agree with him, there are many truly excellent observations,

which the young can scarcely read with due attention, without becoming wiser and better.

Whatever influences the will, is termed a *motive.* The *intentions* are those motives which the mind explicitly dwells upon, and proposes to itself as its objects. The intentions may be good, and yet the really actuating motives very bad. A man may, for instance, have the *intention* of promoting the spread of important truth, when he persecutes those who differ from him, by abuse and calumny, or even by fines, imprisonment, or death ; but his real *motives* will often be those of personal hatred, of pride, of disappointment, of malice, and revenge.

" In all determinations of the mind" (says Dr. Reid) " that are of any importance," (we should say in all whatever,) " there must be something in the preceding state of the mind that disposes or inclines us to that determination. If the mind were in a state of perfect indifference, without any incitement, motive, or reason, to act, or not to act, to act one way rather than another, our active power, having no end to pursue, no rule to direct its exertion, would be given in vain. We should either be altogether inactive, and never will to do any thing, or our volitions would be perfectly unmeaning and futile, being neither wise nor foolish, vicious nor virtuous." We think the former would be the case; and in this paragraph are contained the rudiments of what we would term the *Doctrine of Motives.* Without *motives,* (including under that term every thing which influences the will, either in the state of the body, or of the mind, its tendency to action, its opinions, its judgments, its affections, desires, passions, &c.) there could be no *volition.*

Some of the most remarkable phenomena connected with the will, are those of habit. *Habit* denotes the effects of custom on the motives, on the operations of the mind, and on those of the body in which the mind is in any way concerned. The effects of custom on the *passive feeling,* as we have already stated, is to *lessen its vividness ;* be

the *habit* what it may, the effect of custom is to *increase its power*.

By habit is not only produced a *tendency* to a certain mode of operation, whether directly mental, or in part corporal, but also a *facility* in it. Of this we may find examples in all the common actions of life; in walking, writing, speaking, &c.; and in all the common exercises of the mind, such as memory, judgment, &c.

Many of our mental processes are continually going on without the agency of the will. The operations of the understanding are often in some measure voluntary; but association acts more frequently without our volition, and even without our knowledge. We perceive its agency only by its effects. The influence of the will over the processes and operations of the mind, where gained at all, is only acquired gradually, and by exercise: the trains of thought and feeling, and even the habitual exercise of the memory, imagination, and understanding, often go on without its interference.

The same may be said with respect to the extensive classes of muscular action. Many of those which are by degrees brought under the power of the will so as to be properly termed *voluntary*, were at first produced by the influence of sensation on those mental changes which cause motion, without the will being in any way concerned. In the first state, these are called by Hartley *automatic*. By long exercise, on the other hand, many motory changes, (that is, mental changes producing muscular actions,) which once were voluntary, become so associated with sensations, or with other motory changes, that express acts of volition are less and less necessary, and at last a long series of such motory changes (and their consequently muscular actions,) may go on without the will being in any way concerned. In this case Hartley denominates the muscular action, *secondarily automatic*. The most familiar instance of the transition from voluntary actions to such as are secondarily automatic, is what occurs in instrumental music. Suppose a person who has a perfectly voluntary com-

mand over his fingers, to begin to learn to play upon the piano-forte. The first step is to move his fingers from key to key with a slow motion, looking at his notes, and exercising an express act of volition in every motion. By degrees the motory changes become connected with each other, and with the impression of the notes, through the influence of association; the acts of volition becoming less and less express all the time, till they become at last imperceptible. An expert performer will play from notes, or from the connexion of the several parts of the complex motory changes, and at the same time carry on a quite different train of thought in his mind, or even hold a conversation with another.—This view of the subject, which appears alike agreeable with observation, and with the laws of association, Mr. Stewart utterly rejects; and he supposes, that where the mind is most deeply attentive to some object of thought, all the habitual motions of the body which are exercised at the same time, have some portion of the attention, though we are not able to trace out any relict of consciousness respecting them.

The effect of custom on the motives, is to increase their power over the will. Where that power is become habitual, it often operates in opposition to the dictates of the understanding, and sometimes even to the most impressive feelings of remorse and apprehension. Many of the most ensnaring pleasures of vice, while they lose their vividness, leave behind them a tendency to repetition, which makes its votary more its slave and its victim. The habitual drinker, for instance, when he first began his intemperate course, experienced some pleasure, perhaps to him great, unworthy indeed of a rational being, but unhappily such as to drown the voice of conscience, and to leave the way open to all those causes of riotous mirth, from which sober reflection would derive no satisfaction. His pleasure is necessarily succeeded by a listlessness which makes the customary employments of life unsatisfactory, and leads him to resort again to the scenes of intemperance. By degrees the quantity of his intoxicating draughts must be increased to

produce the same unnatural excitement; that which once placed him on a level with the brute, will not now raise his spirits. He goes on increasing them in frequency and in strength; but the powers of enjoyment gradually lose their tone, and become scarcely susceptible of pleasure. The pains of privation (increasing in proportion to the degree of intemperate indulgence,)—the inability to relish those simple pleasures which temperance usually derives in abundance from the common bounties of Providence,—the restless tendency to repeat that which may give a temporary ease, which all in such circumstances experience, accompanied and heightened, it may be, by the perception of present losses, arising from neglect of business, the consciousness of injury to others, the feeling of decaying health, and the reproaches of conscience,—together urge him on in the path of present and final ruin:—he seeks for relief from his painful uneasiness and melancholy reflection, in that which only increases the causes of them, and makes him still more the slave of sin: and it is too probable that that habit, which is making such depredation in his present means of comfort, which is checking and indeed destroying his best affections, which is weakening his energies of body and of mind, will yield to none of the ordinary motives or discipline of life. These representations are too often true in their full extent; and in proportion as this habit, or any other of sensual indulgence, is exercised, will be its strength, and its destructive tendency.

With this important principle respecting the influence of habit, we should connect another, which is perhaps the most forcible call to moral caution, that though the power of habit is continually increasing, and sometimes even rapidly, though in all cases gradually, *it increases imperceptibly;* and to perceive its progress in others or in ourselves, we must compare its present state with what it was once. And there is still another law of habit, which requires serious thought, and should guide us in the regulation of our conduct; that the strength of any habit is increased, not only by the exercise of

the habit itself, but by the exercise of all which have a direct relation to it. In proportion as the general tendency of the mind, its dispositions and habits of thought and action, are in opposition to self-control, to the promptings of benevolence, or to the duties of piety, will be the increased power of any vicious habit. In proportion as they are favourable to Christian duty, will be the support and safeguard of every one that is accordant with the principles of the gospel. Perhaps it is not too much to assert, that there is no moral habit which does not affect the whole moral system: if it be a bad one, it checks those which are right, it aids the influence of those which duty forbids; and on the other hand, every worthy habit properly exercised, contributes to cherish all those which are allied to it, and to weaken the influence of those which in our best moments we must desire to annihilate.

Conclusion.—Our sketch of this important science is very incomplete; and we have been obliged to omit many things, to which we were desirous of directing the attention of our readers; but we shall be satisfied, if it give them a correct idea of some important fundamental principles which may serve as a guide to them in their own inquiries. If they should be disposed to investigate further the views of which an outline is here given, we may refer them to the articles *Mental* Philosophy and Intellectual and Moral *Education*, in Dr. Rees's Cyclopedia; in which the writer has entered somewhat at large into several of the foregoing subjects, and into others, for which they will now be prepared. But if they have not access to these, or are desirous to advance more rapidly, they may proceed to the works of Stewart, Cogan, Locke, and Hartley. We should recommend them in the first place to confine themselves to the 5th, 6th, and 7th chapters, of the first volume of Mr. Stewart's Elements, since these are the most important, and other parts involve questions for which they will be better prepared, after having read Locke at least. They will then do well to proceed to Dr. Cogan's highly valuable treatises on the Passions; be-

cause these contain a variety of excellent and important remarks on that part of our frame which supplies our chief springs of action; and the study of them, while it will benefit the heart, will prepare the understanding for the more difficult investigations respecting the intellectual powers. The study of Locke's Essay concerning the Human Understanding, should not be delayed any further: and the method which we should recommend is, to peruse the whole with care, marking in the table of contents, those chapters or sections which seem particularly to demand closer study. As they advance in this branch of knowledge, they will often have occasion to refer again to Locke; and parts, which at first appeared of little weight, will afterwards strike them as of great importance. But it would be of great service, if such an abridgment of Locke were given to the public, as should introduce to an acquaintance with all his important principles, without perplexing the young student with those parts which have little to do with mental philosophy, at least in its present state. After having gained an acquaintance with these principles, we recommend our readers to proceed to the study of Hartley's Observations; and in doing this, they will find it very advantageous to leave out, at the first perusal of that work, all the parts relating to the hypothesis of vibrations; or to take Dr. Priestley's abridgment.

After having made this progress, they will be prepared for the perusal of any work connected with the philosophy of the mind, to which their own taste, or accidental circumstances, may direct them. In Mr. Belsham's Elements they will find a valuable summary of the chief topics of metaphysical inquiry, connected with the philosophy of the human mind, together with references to the principal writers who have discussed them.*

* We are indebted to that work, for the plan of the 1st section in the chapter on Association, and for several of the illustrations contained in it. And though originality is of much less consequence than utility, we ought also to state, that in several places we have, without

Many parts of Dr. Reid's works proceed upon very erroneous principles: but the numerous profound and judicious observations they contain, connected with our moral and intellectual processes, will well repay the careful perusal of the student. Mr. Stewart's second volume will also claim his attention; and though his peculiar, and we doubt not erroneous views of the nature of generalization, sometimes warp his conclusions, the profundity and value of his investigations respecting the understanding, can scarcely fail to be admitted by all who are competent to judge on the subject. We must also recommend to our readers, when their minds have been somewhat trained to mental investigation, "Tucker's Light of Nature pursued." There are few works on abstract science so calculated to call into exercise the powers of investigation, and to sharpen the penetration of the understanding. The author is diffuse, and not unfrequently far from precise in his modes of expression; and it is not always easy to ascertain his drift: but his manner, even in the most abstruse parts, is so lively, his illustrations so numerous and striking, and yet so original and appropriate, and his observations, in themselves considered, so strongly marked by good sense, that philosophy is obliged to be continually on her guard, to prevent being carried on, unawares, to conclusions which, in her more sober moments, she must reject. In a variety of instances he has found the truth; and where he is less successful, he schools his reader to activity, acuteness, and vigour of thought.

The perusal of Mr. Stewart's works, will lead to an acquaintance with the French metaphysicians. Among them Condillac holds a distinguished place: and though no one accustomed to think for himself, can follow that philosopher

particular acknowledgment, derived our statements from Hartley's great work, which we cannot but regard as in some measure the Principia of Mental Science. If the reader should happen to have seen a little volume called Enfield's Elements of Mental and Moral Philosophy, he will perceive a resemblance between it and some parts of this book, which we wish to account for, by saying, that a great part of that volume was copied without permission or acknowledgment, from some articles on the subject inserted in Nicholson's British Encyclopedia.

through all his opinions, yet his writings are so perspicuous, and so much marked by good sense and important observations, that they deserve the attentive examination of every student of mental philosophy.

Beside these, the writers on education will furnish many important observations; and in this view we particularly refer to the works of Miss Edgeworth, and Miss Hamilton.

Before persons have acquired the power of entering readily into the discussions of mental philosophy, they will find it of great service, first to read over a work without too much minute attention to the several parts and difficulties which perplex them. After they have gained a general acquaintance with the author's views and principles, they may then proceed with double advantage and satisfaction to the study of the whole. *Festina lente* is the maxim which should be employed in every part of education and self-culture. Above every thing we recommend that mixture of mental humility and independence, which on the one hand, will prevent the hasty rejection of important principles, because we do not at once see how they can be true; and on the other, that submission to mere authority, which will prevent from gaining any consistent principles on subjects respecting which there is great diversity of opinion. The understanding should never be surrendered up to any author; and reflection on what passes within us should be constantly employed as the test of his statements respecting the operations of the mind. It should be carefully recollected, that one great value of the study of mental philosophy is that it habituates the mind to attend to its own states and operations.

To conclude, the love of truth should influence us in all our investigations. The question should always be, not is this speculation ingenious and brilliant, but is it solid and just: and if truth be our real object, and we pursue it with patient attention, and under the guidance of good sense, and judicious reflection and observation, we can scarcely fail to attain what will reward us for our labour, both in the culture of the understanding, and in the conduct of life.

MORAL PHILOSOPHY.

CHAP. XVI.

INTRODUCTION—CONSCIENCE—OBLIGATION.

Object of this Part—Moral Philosophy—Morality—Ethics—Casuistry—Natural Law—Division—Nature of the CONSCIENCE—Formation—Importance as a Moral Guide—MORAL OBLIGATION—Remotest Obligation—Not necessarily the best rule.

MORAL PHILOSOPHY is that science which teaches the nature and obligation of duty. It has not for its object the *precepts* of duty, so much as the *principles* from which those precepts are derived.

In the pursuit of this science, it is of the utmost consequence to *begin* well. If the fundamental principles are correct, and they are made familiar to the mind, they will preserve from numerous errors of great practical importance. The leading object of this division will therefore be, to supply the reader with those elementary views, which may serve to direct and assist him in his future inquiries, and in the work of self-culture. And we are the more desirous of this, because, in the midst of great and striking excellencies, Paley's well-known work on Moral Philosophy is founded on prin-

ciples, which have led the author himself to some erroneous conclusions, and have produced this effect still more among his readers.

Precision of language and correctness of thought, are so dependent upon one another, that it may be worth while to point out a singular error, into which that eminently useful writer has fallen in his very first sentence. " Moral Philosophy, Morality, Ethics, Casuistry, Natural Law," he says, " mean all the same thing, viz. that science which teaches men their duty and the reasons of it:" but he is undoubtedly wrong. *Moral Philosophy* is the *science* of morals: it investigates the grounds and reasons of duty: it traces that quality of actions and dispositions, which renders them obligatory upon a reasonable being like man: it shews what classes of actions and dispositions possess this quality: it ascertains by this means the best rule of life: and it lays down those principles, by the aid of which the rule of life may be most successfully applied.—The terms *Ethics* and *Morals*, though correctly applied to the *science*, are more appropriate to the *art* of *morality*, (understanding by the word *art* as opposed to science, a system of rules for the proper attainment of any end;) and, in this sense, the terms are not strictly applicable to investigations respecting the grounds and reasons of duty. Nevertheless, the *art* of morals can scarcely fail to include some reasoning respecting its foundation and principles, just as the *science* of morals can scarcely fail to include, in some measure, the preceptive part.—*Morality* commonly refers to the quality of an action or disposition which makes it the subject of reward or punishment; but it is also used, (as when we speak of a system of morality), in reference to the art of morals.—*Casuistry* has solely for its object, the *difficulties* of duty; and it classes sometimes with the *science*, and sometimes with the *art* of morals. It often requires subtle investigations, and nice and refined distinctions; and when it is not regulated by invariable attention to the grand principles of morality, it often leads to great intricacy and perplexity. Such discussions

have, indeed, not unfrequently led, through the sophistry of vanity or self-justification, to opinions which confound all moral distinctions. *The moral reasoner must have some fixed points of duty;* and when he has seen that these have a *solid foundation* in the *nature of the human mind,* and the *circumstances of man,* he ought on no account to give them up. If any opinions are in clear opposition to them, the principles on which those opinions are founded, should be regarded as absurd, if not practically dangerous.—The term *Natural Law* denotes that system of duty which is derived from considerations independent, or supposed to be independent, of divine revelation, or the law of God.

Agreeably to the object which has been already stated, we shall pursue the following division.

I. The nature of the *Conscience,* and the necessity of attention to its cultivation.

II. *Moral Obligation.*

III. The *Pursuit of our own good,* not the wisest and best principle of action. The inferior principles of our nature, should be subjected to the control and direction of moral and religious principle. This maxim particularly exemplified in reference to the *bodily appetites.*

IV. *Defective Criteria* of virtue.

V. The *Will of God,* the best foundation of duty or criterion of virtue.

VI. *Essential Characteristic* of virtue.

VII. *Principles* which should have great weight with us in all our inquiries respecting duty: with a particular reference to the universal obligation of *Truth.*

VIII. General rules of *Social Conduct.*

IX. Advice respecting the pursuit of Moral Philosophy.

The Moral Sense, or Conscience.

The Conscience is that internal principle, which, without reasoning, without direct reflection on the *consequences* of actions, or even on their *obligation,* at once approves of certain

dispositions or actions as *right*, or as what we ought to cultivate and practise; and at once disapproves of certain dispositions and actions, as *wrong*, or as what we ought to check and avoid. The human mind is so formed, that the conscience will spring up in it: nevertheless it is equally true and important, that its dictates are not universally the same, and that it is an improvable principle;—that to give it early correctness and vigour, requires great care on the part of those who are concerned in the early periods of education;—and that to give it due *sensibility*, *accuracy*, and *influence*, requires the use of suitable means in every period of life.

The pleasures and pains of the conscience, (like all other mental feelings,) are produced by the ever active principle of association, which, under the occasional control and direction of the understanding, connects, combines, and blends together a vast variety of pleasures and pains; and thus forms a set of feelings, which most powerfully influence the conduct, and contribute most essentially to the happiness or wretchedness of the individual. These feelings are derived from all the other pleasures and pains of our nature, so far as they are consistent with one another, with the frame of our nature, and with the course of the world: (see Hartley, vol. i. prop. 99). They are continually presenting themselves, urging us to shun some branches of conduct, and to pursue others; rewarding us for our obedience, with some of our purest and best satisfactions; and punishing us for our neglect and disobedience, with emotions always painful, and sometimes so agonizing, that life loses all its relish; and all the pleasures which have been purchased by slighting its warnings, lose their power to give more than temporary relief.

As soon as the moral principle begins to appear, a great variety of impressions, some designedly communicated, and others produced as it were accidentally, begin to connect with the terms *good* and *right*, (and others similar to them,) pleasing feelings, derived directly from sensation, or from the approbation of friends, &c.; and with the words *wicked*, *wrong*,

&c., painful feelings, in like manner derived directly from sensation, or from the feelings of shame. If children are so happy as to have parents, whose ideas respecting duty are generally correct, these feelings will be properly directed; and they will then be increased, strengthened, and rendered more and more lively, by the continual addition of many others, derived from various sources. If not, there will be a proportionable deficiency, or erroneousness, in the dictates of the conscience, which will be to be corrected, if corrected at all, by experience, or by increased knowledge, afforded by the Scriptures, or some other rule of life, respecting duty, and the consequences of performing or neglecting it.

But supposing the generally favourable, and not uncommon case, where an individual has had the advantage of an early correct direction of his moral feelings,—here all the pleasures arising from the exercise of the filial affections, all the pains arising, as natural consequences, or as direct punishment, from disobedience, or the neglect of parental injunctions, contribute their share to strengthen and enliven these feelings. As soon as some knowledge of God and of a future life, have been obtained, the affections which are formed towards God, the hope of future happiness, and the dread of future misery, begin to add to the vigour and extent of the feelings of conscience; and they continually, and through life, contribute those impressions, which powerfully tend to give activity and energy to its pleasures and pains, while at the same time they correct and confirm its dictates. Separate from this source, though not independent of it, the beneficial tendency of right conduct and dispositions, and the injurious tendency of the contrary, with respect to the happiness both of the individual and of others, in the way of interest, or reputation, or social comfort, (whether the result of experience, or observation, or pointed out in a less impressive yet often effectual way, by the instructions of parents and friends,) add to the strength and liveliness of the emotions of approbation and disapprobation.

Though the feelings of the moral sense have a general agree-

ment in their force and direction, in different individuals, who have enjoyed the usual advantages for the cultivation of the conscience, yet even in them the component parts must vary considerably, both in kind and in degree. Without attempting, therefore, to enter into a minute account of the formation of those very complicated feelings, composed, as they are, of a vast variety of other feelings, themselves greatly complicated, it may be sufficient to observe, that every pleasing or painful impression, received in connexion with right or wrong conduct, contributes towards the formation or growth of the pleasures and pains of conscience.

Every instance in which approbation, reward, or any other good effects, are actually experienced, or are observed to be experienced by others, in consequence of right conduct,—every instance in which the mind is led to perceive the beneficial tendency of right conduct, its suitableness to the course of providence, and to the frame of man,—every instance in which our own right conduct does good, or gives pleasing satisfaction to others, especially to those whom we love,—every instance in which the heart is impressed with the conviction, that HE who is greater than the heart, knows and approves of sincere and dutiful obedience to his commands,—every thoughtful reflection on the infinitely blissful consequences of a course of steady obedience to duty,—and every instance in which the present supports of obedience are experienced, or perceived in others,—contributes its share towards the formation and strength of those feelings of love and approbation of what is considered as our duty, which make the contemplation of right actions and dispositions, a source of delightful emotion; and which reward the performance of the one, and exercise the culture of the other, by that approving testimony, which has often been an abundant recompence for the greatest pains and privations to which duty may direct.

And, on the other hand, every instance in which displeasure, shame, punishment, or any other ill effects, are actually

experienced, or are observed to be experienced by others, in consequence of wrong conduct, or in which the mind is led to perceive its injurious tendency, its unsuitableness to the course of providence, and to the frame of man,—every instance in which our wrong conduct does injury, or gives painful regret to others, especially to those whom we love,—every instance in which the thoughtful conviction is excited, that HE who knoweth every secret of the heart, is displeased with disobedience, and that the consequence of every act of disobedience, of every indulgence of wrong disposition, of every neglect of duty, and the affections enjoined by it, will, in his all-righteous ordinations, be followed by its proportionate diminution of happiness, or increase of misery, probably in this life, but certainly in another,—every instance in which the present pains of conscience are experienced, or observed in others, in consequence of the neglect of its dictates, or disobedience to them,—contributes its share towards the formation and strength of those lively feelings of disapprobation or even abhorrence, with which we contemplate what, in others, is considered as inconsistent with or contrary to duty, and of remorse, in consequence of wrong actions and dispositions in ourselves; which punish the performance of the one, and the indulgence of the other, with pains that often exceed in vividness, all others to which the human being is exposed in this world; which, though sometimes overcome by the bustle and pleasures of the world, seldom fail to revive in the period of worldly distress, or in the time of sickness and the apprehension of death; and which will, in all probability, constitute a great part of the awful punishments of futurity.

This view of the formation of the pleasures and pains of the conscience, will at once suggest to the thoughtful reader, the means by which it is to be cultivated; and this has been our chief object in stating it.—But in whatever light we regard the *conscience*, one thing is indisputable, that its dictates are not uniformly the same in any one individual; and that they are exceedingly variable in different individuals, even with

respect to the grand principles of duty, and still more with respect to the application of those principles. It is indisputable, that the moral principle grows to maturity from a small seed. It is indisputable, that it is susceptible of culture; that, if neglected, its judgments become wavering and impotent; that if its dictates be made to undergo revision, if corrected by the means of knowledge we possess, and their defects supplied by the more extended views of duty, its decisions proportionably become more firm, and in general more efficacious. (See Paley, B. I, ch. 5.)

Even an ardent desire to keep with exactness the best rules of duty, will not render attention unnecessary to the cultivation of the conscience; (" *I verily thought with myself*," said the Apostle Paul, " that *I ought* to do many things contrary to the name of Jesus of Nazareth;") and an enlightened love of duty must therefore urge to such cultivation. Dr. Cogan, in his Philosophical Treatise on the Passions, (p. 348) adduces as an example of " the influence of perverted principles," " the conduct of a pious Mother towards a most excellent and dutiful Son, who, from a principle of conscience, in opposition to his interests, renounced the religious system in which he had been educated, for another which he deemed more consonant to truth. She told him, that ' she found it her duty, however severe the struggle, to alienate her affections from him, now he had rendered himself an enemy to God, by embracing such erroneous sentiments.' My friend added, that she was completely successful in these pious endeavours; and that the duty which she enjoined upon herelf, was scrupulously performed during the remainder of her days."—The same philosophic writer mentions another instance of the irregularity of the moral principle, in a child, in whose character mildness and compassion were pre-eminent features. " I was once passing through Moorfields," he says, " with a young lady, aged about nine or ten years, born and educated in Portugal, but in the Protestant faith; and observing a large concourse of people assembled around a pile of faggots on fire,

I expressed a curiosity to know the cause. She very composedly answered, I suppose it is nothing more than that they are going to burn a Jew."

From an attentive consideration of the nature of man, as well as from the declarations of revelation, it is clear that the conscience was intended, by the great Author of our frame, to be our guide in all cases of emergency, and to have great influence in every department of duty. It may often be most justly said, that the voice of conscience is the voice of God. Nevertheless, without due care and culture, it may be, and often is, erroneous and defective; and therefore it is not safe as an *exclusive* guide of duty, but should itself be put under the control of a still higher principle, the will of God. It is alike our wisdom and our duty, to enlighten, regulate, refine, and extend the dictates of the conscience, by the law of God, and other intimations of his will, and then submit implicitly to its direction.

Moral Obligation.

Obligation respects voluntary *actions* only.* We say we are *obliged* to walk, if we wish to have health; we are *obliged* to use regular exertion, if we wish to acquire valuable mental habits; and, generally, we are *obliged* to perform certain actions, in order to attain certain ends. The use of the term in this and similar situations, shews its true import. *Obligation* expresses the *necessity of certain voluntary actions, as means, in order to obtain certain ends.* Thus, if the *end* be the possession of health, a *necessary means* is, that we take exercise. If the *end* be the formation of valuable mental habits, a regular series of exertions is the *necessary means:* and, in short, in whatever case we wish to express that certain ends can only be obtained by certain voluntary actions as the

* The term *actions* is here used, to include every mental or corporal exertion consequent on volition. It is thus employed by Mr. Stewart in his Outlines, p. 76.

means, we say we are *obliged* to use these means, in order to obtain these ends.*

Obligation differs from compulsion. The former respects voluntary actions, the latter involuntary. Compulsion always implies some external force. Thus a man is obliged in honour to pay his debts, and if he do not, he will be compelled by the Law; that is, if to satisfy the laws of honour be the end, the payment of his debts is the necessary means; if this obligation do not operate with sufficient strength as a *motive*, the Law will compel him to do it against his will.

Obligation by no means implies an *obliger*. I may be *obliged* by *reason*, by *interest*, by *convenience*, by *honour*, by *conscience*, &c., as well as by the *authority* of another. Authority is one, but not the only source of obligation. Paley's opinion, that "a man is said to be obliged, when he is urged by a violent motive resulting from the command of another," (separate from the very objectionable expression, a *violent* motive,) is by far too limited an account of obligation.

Moral obligation respects those actions which are denominated virtuous or vicious: we are obliged to perform the one, and to abstain from the other, because this is the necessary means, in order to effect a certain end. That is to say, unless we do practise virtue, and abstain from vice, we cannot obtain the ends which wisdom points out as deserving pursuit.

Every question, Why is any one obliged to perform a certain action? gives us, as a final answer, because it tends to the agent's greatest happiness on the whole. When we arrive at this point, it is obvious that we can go no farther. And though true wisdom undoubtedly directs, that in order to attain the highest degree of moral excellence, we should leave our own happiness out of consideration,—and though the human

* This simple and truly excellent view of *Obligation* is taken, with a little alteration, from Mr. Belsham's Elements, Sect. 4. It seems to have been derived from Gay's Preliminary Dissertations, Sect. 2, but with great improvement. In its present form it best accords with our object.

mind is so constituted, that disinterested benevolence, founded upon and supported by piety, would lead an individual who has attained it, to obey the will of God, and seek to promote the welfare of mankind, even if his understanding were convinced that he should thereby entail upon himself consequences highly prejudicial to, or destructive of happiness on the whole,—yet it does not appear that there could be any proper *obligation* to any conduct in opposition to the agent's happiness on the whole.*

Here then we come to the *remotest* obligation of virtue; but the ends of human existence will be most answered, by resting at a somewhat nearer and equally stable ground of obligation. And even assuming it as the *best* source of obligation, it must be evident to any one who carefully considers the laws of our mental frame, and the circumstances of mankind, that the love of God, of man, and of duty, (in other words, the affections of piety and benevolence, and a regard to conscience,) should be our primary aim, since he will be most happy, in whom those principles exist with the greatest strength and vigour.

The *ultimate obligation*, the *best rule*, and the *immediate motive*, of duty, are three distinct considerations. If it appear that to make the will of God our *rule* of duty, is the *best*

* This view of moral obligation is defended with great acuteness, by Thomas Cooper, in the first of his Tracts; his statements, however, are sometimes deficient in that reverence which should ever be maintained to the Supreme Being; there is an occasional vagueness or rather inaccuracy in his expressions; and in some instances we see more indications of acuteness than of solidity. It is less exceptionably, and more compendiously, considered and maintained, in Mr. Belsham's Elements. It is stated by Cooper, (p. 86.) to have been entertained by Cumberland, Puffendorf, Gay, Law, Turnbull, Rutherforth, Clayton, Johnson, and others: Belsham adds Brown and Gisborne; and Paley (see B. II. ch. 2.) may evidently be arranged among them. On this and every other point of morals, however, our decision must be founded on something more secure and satisfactory than human authority.

way to promote our own worth and happiness, as well as the worth and happiness of others, this must be our *best rule*. We may, nevertheless, be acting in perfect consistence with this rule, when we are exerting ourselves for the good of others, or imposing restraints upon our selfish inclinations with an explicit intention to promote the welfare of others, or to follow the dictates of conscience, without, for the time, any direct reference to the will of God as such: benevolence, or a sense of duty is then our *immediate motive*. The remotest obligation in this case, is the same as before; but we can seldom find it necessary, even in theory, to revert to it as the ultimate obligation: for if God is just and good, obedience to his will must be productive of our greatest good on the whole. He is *perfectly* just and good, and therefore in the actual state of the case, (and we need think of no other,) the will of God may, with the utmost propriety, be assumed, not only as the noblest *motive*, and the best *rule*, but also as the *foundation*, and even (with very little departure from logical correctness,) as the *ultimate obligation* of duty.

CHAP. XVII.

REGULATION OF THE INFERIOR PRINCIPLES OF OUR NATURE.

Object of Hartley's Rule of Life—Wisdom and Duty direct that Self-interest should not be made a primary motive—Regulation of the Appetites.

THE laws of our mental frame, and the circumstances of mankind, most clearly point to the truth, that happiness is best secured by acting, in the general tenor of life, without any explicit view to the attainment of it, and steadily following the dictates of duty, of piety, benevolence, and conscience. Hartley, in the invaluable division of his Observations entitled the Rule of Life, has clearly and completely proved this axiom, by a train of investigations founded upon his principles respecting the frame of man. It would give us pleasure to lay before our readers a view of those investigations; but we must refer them, which we do with great satisfaction, to the *Rule of Life*. In the article *Moral* PHILOSOPHY, in Dr. Rees's Cyclopedia, (Div. II. 1—17.) they will also find a kind of outline of that part of Hartley's great work, divested of his hypothetical peculiarities, and in some parts extended by additional illustrations and observations.

In the Rule of Life, Hartley shews, by considerations derived from the laws of the human frame, and a comprehensive view of the *temporal* consequences of actions and dispositions, that the principles and precepts of duty which are taught us by revelation, are the best fitted to promote our present, as well as our eternal welfare. He there proves, that, in the pursuit of happiness, wisdom (equally with duty) forbids us to make any of the lower principles of our nature, our primary aim; requires that we should subject them all to the regulation of the higher principles of benevolence, piety, and a sense of duty; and urges that we make these our primary objects, as steady, habitual, actuating motives.

It may contribute a little to prepare some of our readers for the examination of these positions, if we lay before them an extract from Dr. Reid's Essays on the Active Powers, as given, with a few alterations, in the above mentioned division of *Moral* PHILOSOPHY; and we shall then offer them part of the section on the Regulation of the Sensible Pleasures, derived chiefly from Hartley.

Though a steady pursuit of our own real good (says Dr. Reid) may, in an enlightened mind, produce a degree of virtue which is entitled to some approbation; yet it can never, while the mind rests with this explicit regard to self, produce the noblest kind of virtue, which claims our highest love and esteem. We account him a wise man, who is wise for himself; and if he prosecute his end through difficulties and temptations, his character is far superior to that of the man, who having the same end in view, is continually starting out of the road, from an attachment to his appetites and passions, and doing every day what he knows he shall heartily repent. Yet after all, this wise man, whose thoughts and cares are all centered ultimately in himself, who indulges even his social and divine affections, only with a view to his own good, is not the man whom we cordially esteem, nor who possesses the noble elevation of mind which commands our admiration. Our cordial esteem and admiration are due, are given, only

to him whose soul is not contracted within itself, but embraces a more extensive object; who loves religion, not for her dowry only, but for her own sake; whose benevolence is not selfish, but generous and disinterested; who, forgetful of himself, has the common good at heart, not as a means only, but as an end; who abhors what God and conscience condemn, however attractive its appearance; who chooses, without hesitation, what God and conscience approve, though surrounded with tenfold dangers. Such a man we esteem the perfect man, compared with whom, he who has no other aim than good to himself, is a mean and despicable character. To serve God, and be useful to mankind, without any concern about our own good and happiness, is probably beyond the pitch of human nature. But to serve God, and be useful to men, merely to obtain good to ourselves, or to avoid ill, is imperfect service, and not of that liberal nature which true devotion and real virtue require.

Though we might be apt to think, that he has the best chance for happiness, who has no other end of his deliberate actions but his own good, yet a little consideration will satisfy us of the contrary. A concern for our own good is not a principle, that of itself gives any enjoyment; on the contrary, it is apt to fill the mind with fear, and care, and anxiety. And these concomitants of this principle often give pain and uneasiness, which counterbalance the good they have in view. We may compare, in point of present happiness, two imaginary characters; the first, that of the man who has no other ultimate end of his deliberate actions, than his own good, and who has no regard to religion and duty, but as a means to that end; the second, of the man who is not indifferent with regard to his own good, but has another ultimate end, (perfectly consistent with it,) a disinterested love of goodness for its own sake, or a regard to duty as an end. Comparing these two characters in point of happiness, that we may give all possible advantage to the selfish principle, we shall suppose the man who is actuated solely by it, to be so far enlightened as to see it his interest to live soberly, righteously, and pious-

ly, in the world, and that he follows the same course of conduct, from the motive of his own good only, which the other does, in a great measure, or in some measure, from a sense of duty. The one labours for hire, without any love to the work; the other loves the work, and thinks it the most noble and the most honourable he can be employed in. In the first, it is mortification and self-denial, to which he submits only through necessity; to the other it is victory and triumph in the most honourable warfare.—It ought further to be considered, that though wise men have concluded that virtue is the only road to happiness, and the commands of a benevolent Creator necessarily lead us to consider it as such, yet he who follows it only as a means to an end, and who obeys God only for the sake of the rewards he has attached to obedience, would, in all probability, be continually wandering from the direct path, and seeking for happiness where it was not to be found. The road to duty is so plain, that the man who seeks it with an upright heart, cannot greatly wander from it; but the road to happiness, (except where that confidence in the Supreme Being is formed, which supposes the pious affections to have become, in some measure, disinterested,) would be found dark and intricate, full of thorns and dangers, and therefore not to be trodden without fear, and care, and perplexity. The happy man, therefore, is not he whose happiness is his primary care; but he, who with perfect resignation, leaves the care of his happiness to his Maker, while he pursues with ardour the road of his duty. This gives an elevation to his mind, which is real happiness; instead of care, and fear, and anxiety, and disappointment, it brings peace and joy. It gives a relish to every good we possess; it smooths the brow of anguish, calms the perturbed mind, and makes the pillow of suffering, and of death, the rest of happiness.—(See Active Powers, Ess. III. P. III. ch. 4.)

On the Regulation of the Sensible Pleasures.

Suppose that any one endeavoured to gratify the impulse of his bodily appetites, without any restraint from the virtues of temperance and chastity;—he would soon destroy his bodily faculties, thus rendering the objects of the sensible pleasures

useless; and he would precipitate himself into pain, diseases, and death. "This is a plain matter of observation, verified every day by the sad example of loathsome, tortured wretches, that occur, which way soever we turn our eyes, in the streets, in private families, in hospitals, in palaces." Positive misery, and the loss even of sensible pleasure, are too inseparably connected with intemperance and every kind of impurity, to leave room for doubt, even to the most sceptical. The sensual appetites must, therefore, be regulated by, and made subservient to, some other part of our natures; otherwise we shall miss even the sensible pleasure which we might have enjoyed, and shall fall into the opposite pains, which are, in general, far greater and more exquisite than the sensible pleasures.

The same conclusion also follows from the fact, that inordinate indulgence in sensual gratification, destroys the mental faculties, exposes to external inconveniences and pains, is totally inconsistent with the duties and pleasures of benevolence and piety, and is all along attended with the secret reproaches of the moral sense, and the horrors of a guilty mind. Such is the constitution of our frame, that the formation of mental feelings and affections cannot be altogether prevented; but an inordinate pursuit of sensible pleasures converts the mental affections into a source of pain, and impairs and cuts off the intellectual pleasures.

Upon the lowest principles of *self-interest*, therefore, the pleasures of sensation ought not to be made the primary pursuit of life. Even a mere prudential regard to our own present happiness, requires that they should be submitted to the precepts of benevolence, piety, and the moral sense.

Benevolence enjoins that the pleasures of sense should be made entirely subservient to health of body and of mind, so that each person may best fill his place in life; best perform the several relative duties of it; and, as far as in him lies, prolong his days to their utmost period, free from great diseases and infirmities. All gratifications, therefore, which tend to produce diseases of body, or irregularities of mind, are forbidden by benevolence; and the most wholesome diet, as to

quantity and quality, is enjoined by it. Benevolence also most strictly forbids all gratifications, by which the health or virtue of other individuals is injured, or by which encouragement is given to others, to depart from the rules of chastity or temperance.

The precepts of *piety* are to the same purpose, whether they are deduced from our relation to God, as our common Father and Benefactor, who wills that all his children should use his blessings so as to promote the common good; or from the natural manifestations of his will, in the immediate pleasures and advantages arising from moderate refreshment, and the manifest inconveniences and injuries caused by excess in quantity or quality; or from his revealed will, by which temperance in all sensible pleasures is commanded, and intemperance severely threatened.

In like manner the *moral sense* absolutely directs to the same moderation, whether it be derived explicitly from the foregoing rules of benevolence and piety, or from ideas of decency, rational self-interest, the practice of wise and good men, the disgusting nature of the diseases consequent on intemperance, the odiousness and mischief of violent passions, &c. It is evident, therefore, that all these guides of life, lead to the same end, viz. *great moderation in sensible enjoyments,* though they differ somewhat in their motives, and in the commodiousness of their applications, as a rule, in the particular occurrences of life.

By this steady adherence to moderation, we are no losers even with respect to sensible pleasures themselves: for by these means our senses and bodily powers are preserved in their best state, and as long as is consistent with the necessary decay of the body; and this moderation and its beneficial consequences, directly tend to inspire the mind with perpetual serenity, cheerfulness, and good will, and with gratitude to the Giver of all good.

We are then great gainers on the whole, by religious moderation as to sensible pleasure; still more so as to the sensible pains and sufferings, which the intemperate bring on themselves. These are of the most exquisite kind, and often

of long duration, especially when they give intervals of respite: they impair the bodily and mental powers, so as to render most other enjoyments insipid and imperfect: they dispose to peevishness, passion, and murmuring against Providence: and they are attended with the pangs of a guilty mind.

On the whole, the proper method of avoiding the sensible pains, whether the result of excess, or such as occur in the daily discharge of the duties of life, and of obtaining the sensible pleasures in their best and most lasting state, is not to aim at either directly, but in every thing to be guided by the dictates of benevolence, piety, and the moral sense. It is evident that luxury, self-indulgence, and an indolent aversion to perform the duties of a man's station, not only bring on gross bodily diseases, but, previously to this, often produce such a degree of anxiety and fearfulness in minute affairs, as to make persons inflict upon themselves greater torments than the most cruel tyrants could inflict. There are cases, however, in which persons are obliged, from a sense of duty, from benevolence, from adherence to true religion, &c. to forego pleasure, and to endure pain; and this, where there is no probability of a recompense in this life. Here the hopes of futurity lend their aid; and the present pleasure which these afford, is in some cases so great, as to overpower and almost to annihilate the opposite pains.

"The only rule with respect to our diet," says Dr. Priestley, in his Institutes, "is to prefer those kinds and that quantity of food, which most conduce to the health and vigour of our bodies. Whatever in eating or drinking is inconsistent with, and obstructs this end, is wrong, and should carefully be avoided; and every man's own experience, assisted with a little information from others, will be sufficient to inform him what is nearly the best for himself in both these respects, so that no person is likely to injure himself through mere mistake."

It is sufficiently obvious, that it is the benevolent affections which give the chief value and highest interest to the sensible pleasures arising from the intercourse of the sexes; and it also appears that these pleasures were designed by the great Author of our frame to be one chief means of transferring our affec-

tion and concern from ourselves to others. If, therefore, this great source of benevolence be corrupted or perverted, the social affections depending on it will also be perverted, and degenerate into selfishness or malevolence.* It is more or less corrupted or perverted, by every indulgence of the passions, out of those limits which reason and sound and comprehensive experience prescribe, equally with the revealed laws of God, as best promoting the great ends for which they were implanted in our frame.

These limits are fixed by the marriage institutions, which philosophy, as well as religion, cannot fail to acknowledge, as of the utmost importance to the happiness and improvement of mankind. The direct tendency of these institutions is, to promote the comfort and moral elevation of that sex, to whom Providence has, in a peculiar degree, entrusted the physical care of infancy and early childhood, and the commencement of the habits, on which the welfare of the next race depends; to whom is committed the delightful task, of first developing the powers of the understanding, and cultivating and refining the affections. Independently of this more indirect influence, they essentially aid in the proper care, and the mental and moral culture of the rising generation. They supply a constant and invaluable stimulus for the activity and abilities of the parents. They call into exercise, and cherish in the child, those charities which are the root of general benevolence, and bear a close relation to the affections of piety. And the moral union which they produce between those who form the conjugal relation, has a direct and efficacious tendency, to promote in them the great ends of life, as well as to refine and dignify its present satisfactions and endearments.

To produce the best effects, this union must be inviolable and for life; and it should ever be attended with mutual

* From this place to the end of the chapter, the present differs from the former edition; in which, from circumstances unnecessary to explain, the remainder of the chapter was not written by the Author of this division of the work.

esteem and tenderness, with mutual deference, forbearance, confidence, aid, and sympathy.

The laws of our frame, the plain dictates of experience and observation, and the express and authoritative precepts of the Scriptures, all concur in pointing to steady self-control, as the safest, the wisest, and the *happiest* course; and in directing to avoid, with strict caution, *every* violation of purity and chastity. Ogden well observes on this subject, " Irregularity has naturally no limits; one excess draws on another;" " the most easy, therefore, as well as the most excellent way of being virtuous, is to be so entirely." The laws of the Gospel enjoin that we avoid the indulgence even of impure desires. It is a strict, but it is also a benevolent morality. It checks the evil where it is easiest, where almost alone it is possible, effectually to check it, at the source.

Leaving out of view the mischievous and commonly irremediable effects of impurity of every kind on the health of the bodily system, it is a weighty consideration, that licentiousness corrupts and depraves the mind and moral character, more than any single species of vice whatsoever. That ready perception of guilt, that prompt and decisive resolution against it, which forms one grand feature in a virtuous character, is seldom found in persons addicted to these indulgences. They prepare an easy admission for every sin that seeks it; they are in low life usually the first stage in men's progress to the most desperate wickedness; and, in high life, to that lamented dissoluteness of principle, which manifests itself in a profligacy of public conduct, and a contempt of the obligations of religion and moral probity. Add to this, that habits of libertinism incapacitate and indispose the mind for all intellectual, moral, and religious pleasures; which is a great loss to any man's happiness. *

The moral instructor who is anxious for the welfare of the young, must feel solicitous to induce them to shun the beginning of evils so destructive to their peace and welfare; and he cannot fail to urge them to avoid every kind of in-

* Paley's Moral Philosophy, Vol. I. p. 297.

decent language. The advice of the heathen moralist cannot be too forcibly recommended or too cautiously observed:

> Nil dictu fœdum visuque hæc limina tangat,
> Intra quæ puer est. *Juv. Sat.* xiv. 44.

> ——"Far from the walls where children dwell,
> Immodest sights, immodest words repel;
> The place is sacred."

The Scripture precepts are express on this point: they require us to avoid all "corrupt communication;" and they point to a future account of our words, as well as of our actions.

In innumerable instances, the first step to ruin has been indulging in impure conversation.

To give the dictates of reason, religion, and conscience, their due influence, the disposition to self-restraint should be early and steadily cherished, by those who have the care of the young; and after they arrive at that period in which the passions too often acquire the ascendancy, it should be carefully exercised by themselves. Next to the direct culture and exercise of religious principle, nothing can be more effectual than a full and judicious employment of their time, in the various engagements of their station, in the occupations to which benevolence prompts, in the acquisition of useful knowledge, and in cheerful and active, but innocent recreation. If habits are formed of indolence, and of unrestrained indulgence in sleep, in diet, and in mere amusement, it is in vain to look for that self-control, which was declared to be "wisdom's root," by one, who through the want of it, blighted his fairest prospects, and sunk into an untimely grave.

If we are asked, by any of our young readers, how they may pass through the present period of their lives, with most of honour and of *solid enjoyment*, and at the same time make the best preparation for future respectability, usefulness, and happiness, we should unhesitatingly answer,—think nothing *allowable*, in word or action, which you feel your conscience condemn, and of which you could not speak to a respected friend,—cherish an habitual and operative sense of the divine presence, and your own accountableness,—and remember that "he who despiseth small things, shall fall by little and little."

CHAP. XVIII.

CRITERION OF VIRTUE AND RULE OF DUTY.

Defective Criteria of Virtue—Greatest happiness of the Agent—Qualities necessary for the *best* Criterion of Virtue—Present happiness of the Agent—Good of others—Justice—Moral sense—Understanding—Fitness, Beauty, &c.—The Will of God the best Rule of Duty—Includes every other—Is itself Universal and Invariable—Gives Comprehensiveness and Clearness to the views of Duty—It is a Safe Guide—Carries with it its own Obligation—Required by Revelation—Leads to the principle of Religious Obedience.—Definition of Virtue—Paley's very objectionable—Pearson's too limited—Actions not to be separated from their motives.

It has been already stated that the *ultimate obligation*, the *best rule*, and the *immediate motive* of virtue, are three distinct considerations. Inattention to this distinction has caused much confusion in moral investigation.

On the worth and purity of our motives, depends entirely the value of any action, as far as the individual himself is concerned: and that rule of duty must be the best, which is itself the best *guide* of duty, and at the same time is the most likely to lead to those motives, which, in proportion as they have the chief actuating influence in the mind, exalt it towards the highest point of human excellence. The best rule of

duty will, of course, supply the best *criterion* of virtue; or, in other words, the best test by which to determine whether an action or disposition is entitled to the denomination of virtuous.

Though we set out with the position that the *agent's greatest happiness on the whole* is the *remotest obligation* to virtue, yet it is clear, from the considerations in the former part of the last chapter, that this is not a *motive* on which the mind can rest, without checking its moral progress: it cannot be made a *primary motive,* without defeating its own end. It is equally clear, that an *habitual regard* to one's own greatest happiness on the whole, as the sole end of actions and dispositions, would be continually misleading us from that path by which alone we can reasonably expect to reach the object. It cannot, therefore, be made the criterion of virtue.

To shew that a certain course of conduct is our duty, is a good way of proving that it will promote our greatest happiness on the whole; and, in fact, taking a future life into account, we have no other means of proving it; for nothing can be more certain, than that it is only by a faithful endeavour to discharge our duty, that we can obtain happiness in a state of retribution. That, therefore, cannot be made a criterion of duty, for which duty does itself afford the best criterion.—It would be absurd to employ that as the sole mode of judging respecting our duty, which duty, as well as a regard to our own greatest happiness, requires to be made only a subordinate motive to the discharge of it, and which, in the highest stages of moral excellence, will be entirely left out of sight as a motive.

On this ground, the following statement in Mr. Belsham's Elements, (p. 432,) is very objectionable. " Hence it follows, that *there can be but one rule of right,* namely, the tendency of an action or affection to the ultimate happiness of the agent, or what completely coincides with this, under the government of perfect wisdom and benevolence, to the greatest general good: and all distinctions between what is commer-

cially, legally, politically, &c. right, and what is morally or theologically right, are groundless, absurd, and in practice highly pernicious." The last part of the paragraph is equally just and important: the position in italics, is liable to great and injurious perversion. The effect of an action or affection on the ultimate happiness of the agent, must itself be dependent on the will of God; and that which is itself dependent upon another, cannot be the *only* rule of right, and from what we have already stated, it cannot be the *best*.

It is often convenient and advantageous to employ some one of the less extensive criteria of virtue as, in fact, a means of applying the most general and best criterion. But no quality or effect of virtue can be admitted as the *ultimate*, or even as the *best* criterion, which is in any way arbitrary, or dependent upon peculiarities in the mental or moral character of the individual applying it, which will not include every species of virtue, or which cannot itself be made a primary motive to the performance of it. If any criterion of virtue can be laid down, which is self-consistent, universal, invariable, authoritative, easily applicable, itself excellent as a motive, and perfectly and obviously consistent with the remotest obligation, that must be the *best* criterion or rule of duty.

These principles completely exclude from the rank of the best criterion of virtue, all considerations founded *solely* on a regard to our own *present* welfare, all views of *individual* interest, utility, expediency, &c. *The tendency of virtue to promote our present welfare*, is often a valuable guide; and as a *subordinate* rule may be employed with great advantage: for, in a variety of instances, the present beneficial effects of virtue must be obvious to all who are possessed of any tolerable degree of experiênce and good sense. But these consequences are, not unfrequently, in opposition to *immediate* interests and pleasures; and the most valuable influence of virtue on human happiness, can be thoroughly discerned only by the virtuous themselves: the present effects of virtue can therefore furnish no more than a subordinate test of duty;

and they are in opposition to the highest, so far as they tend to fix the mind upon themselves as primary motives.

The *tendency of virtue to promote the good of others*, though perhaps, in a greater or less degree, directly or indirectly, a constant quality of virtue in all its branches, is often too remote and indirect to be easily applicable, except in those which immediately respect our fellow creatures.—Besides, if this tendency were assumed as the test of virtue, it would have little authority in those branches of self-regulation and piety which do not obviously affect the interests of others.—The conformity of actions and dispositions to *benevolence*, is an excellent and extensive criterion of duty; but we are seeking for that which may be truly called THE *criterion* or rule of duty. Benevolence has a great advantage over the preceding rule, because it cannot too much operate as a motive; it often has a powerful influence in the exercise of the personal virtues; and when supported by the views of religion, must always appear to be consistent with the individual's own highest welfare: but it will not include every species of duty, without a greater extent of moral comprehension, than can reasonably be expected before a high degree of moral worth has been acquired.

Nor can a conformity to *justice* be correctly employed as the criterion of virtue; not even in the sense in which it is taken by the Author of Political Justice, (B. II. ch. 2.) who, as Mr. Belsham observes, (Elements, p. 442.) makes it express "benevolence under the direction of wisdom." A disposition to render unto *all* their due, will, in a variety of cases, perfectly coincide with benevolence, and contribute to prevent the erroneous direction of this principle; and the conformity to justice may with great advantage be made a criterion of social virtue, but no farther. Justice, as a criterion of duty in general, is more defective than benevolence; because benevolence has more influence over the dispositions, and will operate more extensively as a motive, in those cases of duty which are not directly social, and where justice does not appear to

afford any direction, except through the medium of benevolence.—Godwin does indeed "assume the term *justice* as a general appellation for all moral duty," (clearly by this and his subsequent statements excluding from the class of moral duty, the divine and personal virtues;) and he defines justice (p. 127,) to be "that impartial treatment of every man in matters that relate to his happiness, which is measured solely by a consideration of the properties of the receiver, and the capacity of him that bestows:" but he afterwards (p. 150) gives a much more comprehensive account of *virtue*, which he defines "to be, any action or actions of an intelligent being, proceeding from kind and benevolent intention, and having a tendency to contribute to general happiness." According to this, together with his previous theory, virtue is justice in action springing from benevolence in principle: but it is clear that even this definition cannot reach the virtues which respect God and ourselves; because though benevolence may prompt to them, it cannot be said, with any propriety, (nor, we imagine, would Godwin have intended to say,) that they are a branch of justice, especially as he has himself defined it.

If the conformity of actions, &c. to the dictates of the *moral sense*, to the perceptions of the *understanding*, and so on, be made the criterion of duty, it must, from the very nature of those mental principles or powers, as we find them actually existing in the human mind, be an unsteady, ever varying guide. The directions of the well-cultivated understanding, or of the well-regulated conscience, (especially of the latter,) are often an excellent means of judgment; but it is only when they accord with the directions of a still higher and more authoritative principle; and they do not therefore possess those qualifications which would entitle them to be made the *ultimate* standard or criterion of duty.

Still less can the *congruity*, *fitness*, *propriety*, *beauty*, &c. of actions or dispositions, &c. be made more than one criterion of moral worth. The perception of these qualities depends upon the correctness and extent of the understand-

ing, and the moral powers; and they are therefore more exceptionable than the foregoing, as criteria of duty.*

The Will of God, *the best Rule of Duty and Criterion of Virtue.*

No criterion of virtue possesses the qualifications above stated as requisite to make it THE standard of duty, except *the Will of God:* and we now proceed to shew, that this is the best criterion of virtue, or rule of duty. At first sight it really appears unnecessary to prove this. It seems a self-evident maxim, that the will of an infinitely wise, powerful, and good Being, upon whom we are constantly and absolutely dependent, must afford the best guidance to his weak and erring creatures; and it is probable that no consistent and serious believer in the existence of such a being, can entertain a doubt, that wherever the divine will is known, it is our duty to obey it, and that it must be for our interest and happiness to obey it. But the fact is, that in a variety of instances we

* The principal supporters of the theory which represents the obligation to virtue as resting on its being agreeable to the *eternal and necessary fitness of things*, are *Grotius*, *Balguy*, and especially *Clarke;* and to a certain extent it is maintained by the advocates of the opinion, that virtue carries with it its own obligation,—that *the understanding at once perceives* a certain action *to be right*, and that therefore it ought to be performed. This last source of obligation was defended by *Cudworth*, *Butler*, *Adams*, and *Price:* men whose writings display talents of the first order for profound investigation; and whose errors were the errors of confirmed worth, arising from their viewing their own minds rather than the actual condition of human nature, and from their being unacquainted with some of the grand principles of the mental frame, which would have led them to very different conclusions. *Lord Shaftesbury* and *Dr. Hutcheson* make virtue consist in a *conformity to the dictates of the moral sense:* and *Adam Smith*'s theory nearly coincides with theirs. The writers who have made virtue consist in the tendency of actions, &c. to the *agent's greatest happiness on the whole*, have been already mentioned. *Hume* approaches the nearest among the moderns, to the representing of virtue as consisting in the tendency of actions, &c. to promote the *present* interest of man.

are left, even with all the aid of revelation, to ascertain the will of God from the subordinate criteria of virtue; and as these often afford satisfactory grounds of decision, and some of them bring into view motives which form an essential part of moral excellence, the mind is too apt to rest upon them as themselves the foundation of duty, where it would be well to seek one more extensive and invariable.

31 By making the will of God the criterion of virtue, (in other words, our rule of duty,) we do in fact include every other criterion of virtue or rule of duty that is in itself reasonable and just. If for instance, the beneficial tendency or utility of actions and dispositions be proposed as the rule of duty, we reply, that in so far as they really have this beneficial tendency, they must be conformable to the will of God; and that therefore this rule is included under that which should be employed as our grand and invariable guide. The beneficial tendency of actions, &c. may in some cases, (like the dictates of the conscience in others,) be our *only* guide as to the will of God, and may often aid us in the application of the Scripture precepts of duty; and still more frequently they may serve to shew us the grounds and reasons of these precepts, their importance, and their subserviency to the welfare of mankind: but the supposed tendency of actions can never be put against the law of God, as delivered to us by revelation; and should not therefore be made our chief rule. The same may be shewn of every other criterion of virtue or rule of duty: as far as it is self-consistent, consistent with other principles of duty, and really just and useful, it cannot fail to be included under that one which it is alike our wisdom and our duty to make the invariable guide, the will of God.

32 The will of God affords a criterion of duty which is absolutely *universal:* it extends to every part of the external conduct, and to every internal disposition. Some rules of duty leave out of sight important branches of moral excellence: for instance, if virtue be made to consist, as some moralists define it, in doing good to others, in benevolent endeavours to promote the welfare of mankind, those im-

portant classes of duty which respect piety towards God, and the regulation of our own desires and affections, are completely left out of view; and there is no doubt that this deficiency has, in a vast variety of instances, tended to weaken the sense of their obligation, to make them but little thought of, or, if thought of, viewed as not essential to human virtue. When the will of God is made the rule of duty, there can be no such deficiency. His will cannot but respect all our actions, desires, affections, and dispositions. The laws of God, (by which we particularly understand the revealed declarations of his will,) clearly extends to all these; and attentive observance of the course of providence, of the dictates of conscience, and of the frame of man, while they aid us in the application of the divine commands, do also serve to shew his will in a degree, and with a force, proportioned to the extent and accuracy of our observation. And even if there be any cases in which the laws of God fail of application, yet from these sources, the mind which is sincerely desirous of knowing and doing the will of God, can seldom be at a loss to discover what it really is.

The will of God considered as a rule of duty, is an *invariable* principle. As far as we are left to ascertain the will of God from inferior and subordinate rules, this rule must, in some measure, partake of their uncertainty: but with the laws of God to aid and guide us, to prevent confined experience and erroneous conscience from misleading us, it is extremely seldom that there can be any difference of opinion as to duty, where the will of God is honestly employed as the standard. If utility be made the criterion of virtue, or rule of duty, greater or less degrees of experience, greater or less freedom from the perverting influence of selfish feelings, will lead to widely different conclusions, if not with respect to the justness of the grand principles of duty, at least with respect to the extent and application of them. If the dictates of conscience, (unless it be trained by the very rule of which we are speaking,) be fixed upon as the guide of duty, we shall find them

varying in extent, in correctness, and in power, through the influence of fashion, of prejudice, of ignorance, of prevalent opinions and examples. But he who sets out with the will of God as his rule of duty, has a fixed principle which will not bend to the reasonings of the philosopher, to the opinions of the multitude, or to the promptings of passion.—If indeed, we do not seek for it as a *primary* principle of duty, we may sometimes be led to suppose that conduct to be directed by the will of God which is really inconsistent with it. But the more we seek for the guidance of this principle, humbly, sincerely, and earnestly, the more we shall find it; and the more we find it, the more firm, steady, and invariable must our views of duty become, for the will of God itself must be invariable.

Farther, by taking the will of God as our criterion or standard, our ideas of duty will gradually become clear and comprehensive, and this to a degree which cannot be acquired if we were to *rest* in any subordinate rule. Voluntary obedience to the will of God, has an exalting and expanding influence on the mind. If our individual welfare be regarded as the foundation of duty, in so far as we make it our rule, our views would be confined to our own little sphere; we should judge of actions and dispositions only, or principally, in the relation they bear to our own personal happiness; and leaving out of view the intricacies and perplexities in which we should be continually involved, our notions of duty, (unless still guided by the rules of revelation,) would be as narrow and contracted as the principle on which they are founded. The same thing may be observed, though to a less extent, respecting the rules of duty founded upon utility and conscience, unless still further guided by the rules of revelation: so far from expanding as we proceed, our views would then usually become limited by difficulties and objections, which, in the commencement of our moral investigations, we had overlooked. But fix upon the will of God as the rule of duty, with an impressive conviction upon the mind that his will must be right and good, and we discern

more and more clearly the tendency of obedience to promote the welfare of his rational creatures: one moral truth serves as the basis for another: as we advance, difficulties lessen: we see things more as they would be viewed by us, if we could take the whole into account, and forget their relation to ourselves: and we learn to view duty in its whole extent, where other rules would leave deficiencies; we learn to view actions and dispositions without that undue reference to their *immediate* consequences, to which the subordinate rules of duty, when not directed by this higher principle, must too generally confine us.

The will of God, considered as a rule of duty, is in an eminent degree *a safe* guide. Several eminent moralists have made general expediency the criterion of virtue. But it is plain that beings who cannot see the consequences of any action in their whole extent and connexions, must often be inadequate judges of general expediency; and that if they take this as more than a subordinate rule of duty, they must be continually misled by their ignorance and selfish prejudices. The true plan undoubtedly is, to ascertain, as far as we can, what is our duty, taking the will of God as our rule and guide; and then to pursue it without thinking too much on the particular consequences of our observance of it. "The happiness of the world," as Bishop Butler admirably remarks, "is the concern of Him who is the lord and proprietor of it; nor do we know what we are about, when we endeavour to promote the good of mankind, in any way but those which he has directed."—Even benevolence will sometimes do harm, unless it is under the guidance of religious principle.

The will of God is a rule which carries with it its own obligation. We may indeed be told, that we have ourselves admitted one ground of obligation beyond it, which is brought into view by that definition of virtue, which makes it consist in its tendency to promote the ultimate happiness of the agent: and it is to be allowed, that we may ask with reverence, Why should we obey the will of God? But the

answer is plain and obvious: Because under the government of an infinitely wise, good, and powerful Being, obedience to his will must secure our greatest welfare. When once asked, it is a question which never need be asked again. Its answer is a self-evident and necessary truth. We say therefore that this rule carries its own authority along with it. We cannot think of any *higher* obligation than the command of that gracious Being under whose government we live, and upon whom we depend now and for ever. We have nothing to do but to know what his will is, and then obey, with full security that we are doing what is wise and right, what in fact is best for others and for ourselves. And we must again observe, that if we make the tendency of our actions &c. to our own ultimate happiness, the criterion of virtue, we have no more sure and general guide as to that tendency, than the will of him upon whom our ultimate happiness depends; so that take whatever view of it we will, we come to the same conclusion.

It is impossible for any one who regards the Scriptures as the authentic records of divine revelation, to hesitate in admitting, that the principle of *religious obedience* is the foundation of duty, and that we cannot fulfil our duty, without making the will of God our rule of life. The express declarations of the Scriptures, the examples they present to our imitation, and the views they unfold as to the relations in which we stand to God, all point to this truth.

Lastly: the employment of the will of God as our *rule* of duty, must almost necessarily lead us to make the will of God our *motive* as well as our guide. We are so formed, that what we pursue as a *means*, will gradually become our *end*. In whatever way we learn the will of God, (whether by the course of his providence, by our consciences, by the frame of man, or, above all, by revelation,) if we steadily employ it as our rule and guide, (although, in the first instance, because it is our wisdom to do so, because thus we shall best promote our own welfare,) it must, as we proceed, be continually

obeyed without any explicit reference to its consequences to ourselves; and in proportion to the frequency and consistency of voluntary obedience to the will of God, it will of itself become our ultimate object.—Besides, if we take the will of God as the guide of duty, it cannot fail to teach us, (what other rules too often leave out of sight,) that it is our duty to cultivate the disposition to obey him, to shun his displeasure, to fear him, to love him, to trust in him, and to serve him; and we cannot therefore doubt, both from the natural tendencies of the mind, and from those views of duty which the will of God communicates, that if we do make it our guide, we shall necessarily be led to make it our motive.—Habitual, universal, voluntary, intentional obedience to the will of God, must be the highest point of excellence among all his rational creatures. This motive must carry along with it, worth and happiness, security and peace, in proportion to the steadiness and extent of its influence. This the frame of man, and the course of providence, and the light of revelation, most expressly and forcibly teach us. In proportion as the will of God becomes our motive, shall we see clearly, and discharge steadily, the whole of our duty: in that proportion shall we become like him whose grand end and aim was to promote the glory of the great Being who sent him, and to finish his work: in that proportion shall we become partakers of the divine nature, and the will of God become our will.

DEFINITION, *or Essential Characteristic,* OF VIRTUE.

WHEN we consider the speculations of philosophers, on the subject of moral obligation and the rule of duty, and observe the great diversity which exists among them as to the *theory* of virtue, we might naturally expect to find great difference in the *application* of their system to the practical principles of morality; but where they have been in any considerable degree guided by the morality of the Gospel, it will seldom be found that they differ widely on any essential point. Yet it is not a matter of slight importance, what we lay down for our-

selves as our fundamental principle of duty: some principles are more confined, others more accommodating; and our views of duty will usually be found to be clear, extensive, correct, and impressive, in proportion as the principle is so, which we employ as our foundation.

The fact is, the idea associated with the term *virtue*, or *rectitude*, or *moral worth*, is so exceedingly complex, formed of so many notions and feelings, that no definition can directly include them all. All that can be expected from a definition is, that it shall include every object to which the term can justly be applied, and exclude every other: but, (in such a case as this at least,) it is in vain to look for one which shall bring into view all the associated circumstances. These will depend upon the mental and moral character of the individual, upon his experience and observation, &c. And it is owing to an inattention to this circumstance, that so many definitions have been given, which in reality are essentially defective; though, through the unobserved influence of other views, they have not excluded in the minds of those who have laid them down, classes of human conduct and dispositions which are certainly a part of moral excellence, but to which those definitions do by no means extend.

Paley's definition (vol. i. p. 41.) which is copied from Gay's Preliminary Dissertations, is peculiarly defective, yet at the same time redundant. "Virtue," he says, "is the doing good to mankind, in obedience to the will of God, and for the sake of everlasting happiness. According to which definition," he continues, "the *good of mankind* is the *subject*; the *will of God*, the *rule*; *everlasting happiness*, the *motive* of human virtue." If Paley's acquaintance with the principles of mental science had been more precise and extensive, it may reasonably be supposed that his clear judgment would have framed a definition much more satisfactory than the one he has adopted.

In the first place, what he terms the *subject* of virtue is radically defective: it excludes, because it does not include, the personal and divine virtues; and yet, in the very next page,

he speaks of the division of *virtue* into the duties towards *God,* towards other men, and towards *ourselves.* It is clear, nevertheless, that Paley's definition does not include reverence, gratitude, chastity, temperance, &c.

Next, his mode of stating his *rule* is inaccurate. If it is said that we do a thing in *obedience* to the will of another, it is obviously implied that we not only do it conformably to his will as a rule, but having the intention to obey it as our *motive.* As the expression stands, it excludes from the character of virtuous, every action which is not influenced, directly or indirectly, by the disposition to obey God; and it is liable to the objection which we shall hereafter make to a definition much more satisfactory than Paley's. If it were designed to represent the influence of religious obedience as an essential part of virtue, it excludes a vast deal of what is usually regarded as justly included under the appellation. If the expression *in obedience* were intended, as we suppose, to imply no more than *conformably* to the will of God, it must be regarded as an important verbal inaccuracy; and the expression for which it stands, would have rendered unnecessary the statement of the *subject* of virtue. If the *will of God* be the *rule* of virtue, *conformity* to that rule, in its various objects, must be virtue itself: and if this had been taken as the criterion of virtue, it would have been equally needless and embarrassing to introduce any specification of those objects.

As to the *motive,* this is still more objectionable than the *subject:* for it excludes, not only the virtuous actions of those who do not believe in a future state, but even those which spring from a *disinterested* regard to the welfare of others, to the will of God, or to the dictates of conscience: that is, when an action becomes the most virtuous, it ceases, according to the definition which Paley has adopted, to be virtuous at all.

We do not wish to go so far as one excellent writer has done, and say that virtue is *voluntary obedience* to the will of God. Undoubtedly every act of obedience to the divine will,

is an act of virtue; but an action may surely be virtuous, which does not include an *explicit* reference to the will of God, which is not produced by the *immediate* operation of regard to his will. Where the mind is habitually under the influence of a regard to the divine will, this principle will indeed operate, directly or indirectly, in almost every action, and in almost every instance of the exercise or restraint of the affections: but should we therefore deny the character of virtuous, to actions in themselves right, where the motive also was right, (for instance, a strong sense of duty, a disinterested desire to promote the happiness of a fellow creature,)—or should we deny the character of virtuous to such motives or dispositions,—because for the time at least, there was no direct intention of obedience to the divine will, or even any idea then present to the mind, that we were in reality acting agreeably to the will of God? It is further admitted, that the character of the action is greatly heightened, if it not only spring from a sense of duty, and a desire to do good, but also from the belief, that it is agreeable to the divine will, and from the desire to obey it: indeed it has then reached the highest point of excellence: but we contend, that an *action is truly virtuous*, if it be *in itself right* (i. e. conformable to the will of God,) and spring from a sense of duty, or a desire to do good; and this in proportion as these motives are pure, i. e. free from an explicit regard to our own real or supposed good. The excellent writer to whom we have referred, (Pearson in his remarks on Paley,) has taken as a definition of virtue, one which only includes the perfection of virtue. We can think of no higher degree of it, than what he lays down as essential to it, *voluntary* obedience to the divine will. It was the distinguishing excellence of our Saviour's character, that it was his habitual object and aim to do the will of God; and in so far as his diciples imbibe the spirit of their venerated Lord, they will approach that height of excellence in which the will of God will be their will, and his glory their chief aim. But if we refuse the

character of virtuous to all actions, but those which directly spring from this ennobling motive, we must not only say that the speculative atheist cannot be in any degree virtuous, however much he may act from a sense of justice, of benevolence, &c.; but we must deny the appellation of virtuous to the most worthy, just, generous, or humane actions of those, who while they believe in the existence and government of God, yet have little, if any explicit regard to his will. Their virtue is *defective*, both in its extent and in its worth. Their characters want that grand quality which is essentially requisite to complete excellence, and which would not fail to give them stability and purity; but in so far as they observe the laws of benevolence, truth, uprightness, temperance, &c., from a sense of duty, a desire to do good, or any other motive *consistent* with the will of God, their conduct is virtuous, and their motives are virtuous also.

The real excellence of Pearson's principles of morality, (which have their foundation in religion, in a regard to the will of God,) will be preserved, if we define *virtue* to be *the conformity of dispositions, and of actions which result from them, to the will of God.*

And here we must observe, that the views of duty which Revelation unfolds to us, will not allow us, when we speak of *actions* as virtuous, to separate them from their *motives*. Actions may, in themselves considered, be right, and yet as far as respects the agent, have no moral character, because they spring from no worthy principles within: they may, as far as respects the agent, be even sinful, because, though right in themselves, they spring from sinful motives: for instance, the libertine may afford pecuniary aid to a distressed family, in order to gain the confidence, and ruin the happiness, of one of its dearest members.—On the other hand, right motives cannot make a wrong action right. The agent may not be culpable, since his conduct might be wrong solely through unavoidable ignorance; but though his motives may excuse him in the sight of God, they cannot alter the nature of his

conduct. The persecutor may really be influenced by the idea of doing God service, and may suppose, that what he does is right; but his acts of persecution are not thereby deprived of their real character: they are wrong, and can be made right by no motives whatever. *To entitle an action to the appellation of virtuous, it must not only be right,* that is, conformable to the will of God, *but it must spring from right motives,* that is, such as are conformable to the will of God.*

* On this point see Mr. Belsham's 7th section, entitled the Moral Value of an Action estimated; and also Dr. Price's Review of the principal Questions and Difficulties on Morals, chap. 8, and 9.

CHAP. XIX.

PRINCIPLES AND RULES OF DUTY.

Principles which should have great influence in all our inquiries respecting Duty—Universal Obligation of Truth—Rules for Social Conduct—Justice—Capital Punishments—Justice respecting Property—Reputation of others—Liberty of Conscience—Promises—Reparation of Injuries.

IGNORANCE is an excuse for departures from duty, only where it is unavoidable. If it arise from the want of a sincere desire to seek and find the true path, or from an indisposition to see the truth, because the truth will probably condemn, ignorance partakes of the criminality of those sources of it, and is responsible for its consequences. And the true way to acquire stability and consistency of conduct, is, to enlighten the conscience before hand, to form judicious steady principles of action, and to submit to their guidance, without allowing the immediate consequences to enter much into calculation. To assist our readers in this object, is our design in laying before them the following principles, peculiarly referring to the difficulties of duty, but more or less applicable in all departments of moral investigation.

(1.) *General rules of duty are absolutely necessary for the moral welfare of man;* and therefore, whatever tends to weaken the influence of any such rule, is, in itself considered, an evil.—To perceive the necessity of general rules of duty in the present condition of human nature, it is simply requisite

to consider what would be the state of things without them. We should then be under the necessity of calculating, in *every* case that comes before us, on which side the good or evil attending the proposed action preponderates. In fact, our lives must then be a series of *mere calculation*, and the active employments of life must be interrupted, or altogether neglected. We should be obliged to decide, in numerous cases of continual occurrence, without possessing the means of judging as to the consequences of our actions. The great mass of mankind would be left without any guide. All would be left under the influence of emotion, prejudice, and self-love; and no consistency or regularity could be expected in the moral conduct of men.

We are, not unfrequently, unable to trace completely even those consequences of actions, which are immediate and apparent; still less those which gradually arise in the silent lapse of time. The consequences of actions may last, when the agents have long finished the journey of life. Our actions may influence others; our deviations may directly or indirectly produce more extensive deviations, of which we shall have and can have no knowledge. Perhaps there is scarcely an important action of our lives, the consequences of which are confined to ourselves, or even to our own sphere of observation.

Besides, if we were unable to lay down general rules for moral conduct, and were obliged to decide upon each action as it occurred, it is scarcely possible that we should avoid the influence of heated feeling; and we should seldom possess that abstraction of mind, which would enable us to leave the present out of consideration, and view with calmness and impartiality the real tendencies of our actions. The cases are innumerable, in which interest or passion paint in vivid colours the course to which they prompt; and throw into the back-ground, and render almost imperceptible, the dangers which should induce us with steady firmness and perseverance to avoid it.

From these considerations taken together, it may be regarded as indispensably necessary, that there should be general rules for directing the moral conduct; and from this it immediately follows, that *every deviation from a general rule of duty, must in itself considered be an evil.*

(2.) In considering the consequences of departing from a rule of duty, we must not confine ourselves to the *immediate* consequences; but must also take into account the ill effects arising from the limitation of the rule itself, the tendency of one limitation to furnish ground for another, the tendency of one departure from the rule to lead on to another, to weaken its authority in our own minds, to weaken its authority in the minds of others, and so on.

(3.) *Expediency* must always give way to *right*. *Expediency* peculiarly refers to those consequences of actions which come within the sphere of our own actual observation; and, of course, our views of it must depend upon the comprehension of our minds, and upon the extent of our experience and observation. *Right* takes the whole into consideration, and rests most on established principles of duty, particularly those derived from the divine law. As soon as a person has, by any means, satisfied his mind respecting the will of God in any particular case, he then knows what is right for him. *Expediency* is peculiarly the subject of *prudence*; *right*, of *duty*. —Though it is often the part of duty, as well as of prudence, to do that which is most expedient, yet where expediency appears to oppose a clear rule of duty, we ought not to hesitate in our choice. The right, pursued aright, must always prove, under the government of infinite wisdom and benevolence, the most expedient.

(4.) Where the rules of duty are not only agreeable to the dictates of conscience, and to those conclusions which are drawn from an extensive consideration of the external and internal consequences of actions, of the frame of man, and the course of providence, but are also sanctioned by the express authority of revelation, they ought not to be violated except in

cases of absolute necessity; that is, when after a serious deliberate examination they appear to us to interfere in their direction. In such cases, (which however are very rare even in our present state of knowledge as to duty, and which in all probability will hereafter altogether disappear,) we must, to the best of our abilities, balance the importance of their directions, and decide by the result. According to the old maxim, we must, of two evils, choose the least.

(5.) If ever the rules of duty appear to interfere in their directions, we must be considerably guided by the comparative importance of the rules themselves. In forming the comparison, we must take into account, not merely the consequences of the particular case, but also the strength and universality of their obligation, the consequences which would follow from their being generally neglected, and the common tendency to such neglect; and also the nature of the consequences, whether they affect the religious and moral welfare of ourselves and others, or respect temporal interests merely. And, again, we must consider whether the rules are clear and definite, or whether they are by their nature indeterminate: because where they are clear and definite, the violation of them is obvious and certain; where they are indeterminate, the violation of them may be in appearance only; and the consequent ill effects on the minds of others, will usually be less in the latter case than in the former.—Some may perhaps think, that if all these calculations are to be made in cases of duty, the way of duty must be indeed difficult and perplexed. The fact is, we are now speaking of cases which, if the mind be under the guidance of religion, are of rare occurrence. A humble devout heart is the best preparation for knowing our duty. The wisest among the sages of antiquity has well said, "Trust in the Lord with all thy heart, and cleave not to thine own understanding: in all thy ways acknowledge him, and he shall direct thy paths."

(6.) It appears to be a clear and important moral principle, (founded, in a great measure, on the foregoing considerations,)

that the violation of any rule of duty is wrong, unless it is right; that is, unless it is required by some other rule which, in the particular case at least, requires the preference as more urgent and important. For instance, obedience to parents is a clear and positive duty; and when no higher duty interferes, disobedience cannot but be wrong: but it may happen, that a parent commands what is forbidden by the laws of God; and it then is not only right to disobey, but it would be wrong to obey. With respect to the rules of duty, there is, we apprehend, no middle course. If no higher rule interferes with the operation of that which respects our own case, it is our duty to obey it: if a higher rule does interfere with it, it is our duty to neglect it. In every case of moral conduct, there is but one right course: every other must be wrong. Not that all the rules of duty are of equal importance: still less that there are no degrees of right and wrong as far as respects the motives: but that our actions, to have any moral character at all, must either be right or wrong. There is no neutrality in duty.

Universal Obligation of Truth.

A *lie* is *a falsehood told with a design to deceive*. Whatever be the motive leading to the employment of it, it is equally a lie. The moral culpability of the individual may be lessened or increased by the motive; but nothing more. We may call it by the mild appellations, *untruth, falsehood, departure from truth*, &c.; but the nature of the thing is not altered. A falsehood told with the design to deceive, is a lie. —The expression, a *departure from truth*, does not invariably imply any *intention* to deceive; a *breach of truth*, according to common usage, always does.—*Veracity* expresses the disposition to adhere strictly to truth: it is uprightness in our words. A *departure from veracity* always implies an intention to deceive; and still more forcibly does a *breach* of veracity.

It is an important maxim in morals, as well as in education, to call things by their right names. The odium of vice is

often lessened by mild expressions respecting it. And, on the other hand, moral distinctions are often confounded, by giving to things, in themselves harmless, appellations which properly belong only to what is morally culpable. *Fictitious narratives* e. g. are not lies: if the author pretend that they are founded on fact, or that they are true, when such is not the real state of the case, that *assertion* is a lie; but the *narratives* themselves are not lies. In like manner, the *exaggerations* too common in conversation, and those falsehoods which solely arise from unfortunate mental habits, without any intention to deceive, and those *expressions of complaisance*, which though not true in their strictly literal sense, are so in the way in which they are universally interpreted,—these ought not to be called lies. We do not say that they are altogether free from moral culpability; but it is not that of intentional deception. The exaggeration, or the expression of complaisance, may be *intended* to deceive; and then it becomes a lie: and in proportion as it verges to this point, is its culpability. The culpability of the other departures from truth depends upon the degree in which the individual has been negligent in his endeavours to check, or to correct, so injurious a habit: in itself considered, it has no moral quality.

The above is the only definition of a lie, which appears precise and intelligible; and it is accordant with the serious use of the term in common language. Paley has contributed to cause great incorrectness of expression, and even great laxity of principle, on this subject; and when we see that eminent writer expressing himself so loosely, as to speak of those falsehoods which are not criminal, as not being lies, and laying down as a maxim that falsehoods are not criminal "where the person to whom we speak has no right to know the truth," we feel apprehensive of the consequences, and should rejoice to be able to prevent them, in any instance, by those principles of morality which our rule of duty decidedly prescribes on the subject.

Paley does, indeed, qualify a little the random position we

have quoted from him, by adding, "or more properly, where little, or where no inconvenience results from the want of confidence in such cases;" and his illustrations are cases of an extreme nature: but he still founds the obligation of truth upon a balance of known or supposed advantages, or even of conveniences; and his authoritative decisions on this point have, we doubt not, often led to departures from truth, where an unbiassed judgment must have known at once what was the way of duty.

If in any case benevolence *seem* to require a breach of truth, let the following considerations be fairly weighed.—The falsehood must be an evil, as a violation of a positive rule of duty, expressly enjoined and strongly sanctioned by the revealed will of God. It must be an evil, because that rule is of the utmost consequence to the temporal and spiritual welfare of mankind: for words are the grand medium of all the influence we have over the happiness of others; and mutual confidence is necessary to this influence, not only in cases of present interest, but in those which are most closely connected with our eternal well-being. It must be an evil, because that rule is clear and intelligible; admitting of but one meaning, and that perfectly precise and definite:—because the rule is universal in its application, in no case made to depend upon consequences, but absolute in its injunctions, and in no instance inconsistent with itself:—because the rule is upheld by the authority of the conscience, where this is enlightened by Christianity, and cannot be slighted without neglecting its dictates:—because the rule is so strict, precise, and extensive, that scarcely any exception can be imagined, which, if allowed to be right, will not justify others, and these justify or palliate others, and so on; thereby weakening its authority and its value, and making way for those baneful effects which necessarily arise from the common neglect of it, in proportion to that neglect:—because the obligation of this rule is superior to that of the other rules of social duty, inasmuch as they require truth, and, therefore, it has their obligation to support it; and at the

same time it has an obligation of its own. In most cases, benevolence clearly enjoins a strict adherence to truth, and in like manner does justice; and justice never sets any limit to its obligation. This of itself would make truth a duty: but besides this, its authority rests on the strong declarations of the conscience, and upon the more steady unvarying declarations of the law of God, and, therefore, upon its powerful and all-important sanctions.

Against all this, he who is determined to adhere to duty cannot, with any consistency, place any selfish interests; no one at least can suppose that the greatest worldly interest can *outweigh* the obligation. But the limits which appear sometimes to be set to it by benevolence, have cost many a perplexity and many a struggle; and too probably many a departure from truth, and we doubt not many a bitter pang of remorse, when the mind has ceased to be guided by the impulse of feeling, and when the conscience has become enlightened by a steady principle of religious duty: for though we cannot but suppose that He who knoweth our frame, will make every allowance for our wanderings from the narrow path of duty, which not selfish anxiety, but real, though not enlightened benevolence, has produced; yet piety, whenever it gains its full sway in the heart, will make it feel its weakness, if not presumption, in supposing that the good of the creature might lawfully be sought by means which the all-wise Creator hath forbidden. The commands of God must be a better guide for promoting the welfare of mankind, than those affections, which though implanted by Him to excite us to promote it, are capable of a wrong direction, and clearly require the support and guidance of a higher principle. Benevolence, considered as a *rule* of duty, never can be inconsistent in its directions, because it requires us to do the *greatest* good in our power; and pious benevolence must always feel a confidence, that this will be best accomplished by a steady adherence to that course of duty, which infinite wisdom and benevolence has prescribed: but benevolence, as it refers to our

own *feelings*, is often inconsistent in its direction, and may mislead us;—it may dwell upon some supposed good, or means of good, when some other ought, in the eye of reason, to be the end proposed;—it may be directed to one object, when if our comprehension were enlarged, we should give the preference to another;—and, (what is most to be apprehended,) where not completely placed under the direction of piety, it must often be subject to the capricious inconsistencies and partialities arising from self-love. Where, however, the heart is devoted to do good, and common prudence is employed in effecting it, we need not be afraid of following the dictates of the benevolent affections, unless they interfere for the time with some higher principles; nor should we be too scrupulous in our calculations, lest we lose means and opportunities which cannot be recovered: but wherever our feelings prompt us to sacrifice so important a principle of duty as truth, in order to do some supposed good, let benevolence represent that it is not immediate good, or temporal interests alone, which are to be taken into account, but future evils also, and the spiritual well-being of others and ourselves; and if even then conscience is undecided, let piety say, whether in the departure from an acknowledged, strict, express, unlimited rule of duty, we can hope for the approbation of Him who seeth the heart. One whose noble sacrifices to a sense of duty, will ever endear his memory to all, of every religious persuasion, who know and can appreciate their value, (we refer to the excellent Lindsey,) has well said, "God does not want our sinful acts;" and one whose authority must rank high with the Christian, has taught us not to do evil that good may come. Obedience to the will of God, must in all cases be best for frail erring man.

If any case can be pointed out, in which, all things taken into account, it is *right*, our *duty*, to depart from truth, then, and then only, can such a departure cease to be wrong, or contrary to duty. No exception to a rule of duty can be admitted, which we cannot make itself a rule of duty: and to

so clear and definite a rule as that of truth, no exceptive rule can be admitted, which is not itself perfectly clear and definite.*

We are fully aware, that to adhere steadily to this branch of duty, sometimes requires considerable fortitude; and, sometimes, to make truth really beneficial in the particular instance, much presence of mind: but it is not the only case in which these important qualities are requisite. Real fortitude is essentially necessary in almost every department of duty: and nothing contributes more to produce it, and at the same time to produce a proper degree of prudence and presence of mind, than having fixed principles of moral conduct, and proposing to ourselves nothing more than a single steady aim to discharge our duty,—nothing, we should say, except that which is itself of the first consequence to the means, as well as to the end, a humble dependence upon Him, who condescends to call himself our Father, a constant regard to his will, and the desire of his approbation as our chief good.

Regulation of Social Conduct.

The fundamental rule or principle of social conduct, laid down by universal unlimited benevolence, is, that in all instances where others are directly or indirectly concerned, we should aim to promote the greatest degree of happiness in our power, and to cause the least degree of misery. This rule, however, can be rendered efficacious, only by employing subordinate rules, which may be more easy of application to particular cases, and from which nothing but their inconsistency in any instance with the more general principle, should induce us to swerve.

* In the last division of the article *Moral* Philosophy, (already referred to,) the reader, who is desirous to enter more particularly into the supposed limitations of truth, will find some considerations respecting them, which, if not in every respect satisfactory to his mind, may assist in giving firmness and precision to his principles of veracity.—The *extreme* cases in which the obligation of truth has been supposed to cease, are of very rare occurrence; but when an exception is admitted to a rule

The Scripture precepts, taken in the natural and obvious meaning of them, furnish here, and in every other case of duty, an inestimable direction. The rules and observations which follow, are in no way designed to supersede the employment of the Scripture precepts; but all are either directly derived from them, or intended to assist in the application of them. These precepts, and the dictates of the moral sense, (which, in the mind that has received a Christian education, must usually coincide with them,) are the chief supports of all that is good, even in the most refined and philosophical, as well as in the vulgar; and, therefore, they ought not to be weakened or explained away.

Having already said what appears requisite for our purpose on the duty of truth, we proceed to observe: I. That benevolence most forcibly directs to strict impartial justice in all our social transactions and relations. By *Justice* we understand, the regulation of our conduct by a steady regard to the rights of others, where our own interests or passions are concerned. Where this principle is prompted and regulated by a sense of duty, by the benevolent affections, or by a regard to the will of God, it may be considered as comprehending every branch of the duties, which we owe to our fellow men. If we "render unto all their due," taking the expression in its widest extent, we do all that the Supreme Being requires from us in our intercourse with others; for we shall then be kind

of duty, (unless it can be so well defined as itself to form a rule,) there is no knowing when to stop. The shades of distinction, in cases of moral conduct, are often so much blended, that it requires a very discerning eye to perceive their limits; and all know, that when the selfish feelings of ease, of pleasure, or of profit, are concerned, they never fail to throw a film over the eye of the understanding, and greatly obscure its power of discrimination. Those supposed exceptions to truth, which are of an extreme nature, seldom fail to lead the speculative philosopher to others, in which the way of duty seems to the Christian moralist perfectly clear; and these again at least furnish excuses, and sometimes imaginary justification, for departures from truth, in which those who judge by the standard of revelation, can see nothing but guilt.

and humane to all with whom we have connexion; we shall be desirous of their welfare, and earnestly endeavour to promote it; we shall cultivate truth, and fidelity, and uprightness; and we shall properly discharge the duties of our several stations and relations. In this extensive application of the term *Justice*, it nearly coincides with *Benevolence*; but in its more limited and customary acceptation, the two principles admit of a clear distinction. A man may be careful to avoid encroaching upon the rights of others, and he may give to all what they have a right to claim from him as a debt of justice, and yet may have very little benevolence, and do very little from the promptings of the affections which it includes. And, on the other hand, we may be led away by the impulse of those affections, to neglect the strict claims of justice. But in proportion as a sense of justice springs from Christian principle, will its direction coincide with those of benevolence; and the just, the upright, the righteous man, will, in the best sense of the expression, be a *good* man.

To consider in detail the directions of justice, would obviously be impracticable in this work: but we shall suggest an outline of them, to assist in directing our young readers in their own inquiries and reflections, enlarging a little on some parts as we proceed.

1. Justice requires that we abstain from all injury to the *lives* and *liberties* of others.—The leading exceptions generally admitted to the first object of this rule are, where we endanger, or actually take away, the life of another, for the sake of self-preservation;—the destruction of life, in wars undertaken for the defence of national safety or liberty;—and the capital punishments inflicted agreeably to the laws of the country. As to these last, it may confidently be admitted, that those who take any share in them, (as accusers, witnesses, jurymen, judges, or executioners,) are not guilty of any injustice. But when it is recollected, that at least one hundred and sixty species of crime are, by our English statute-book, made punish-

able with death,—that the sole justifiable ends of punishment, are, the reformation of the offender, the prevention of crime, or both united,—and that actual experience has clearly proved, that capital punishments are less effectual for the prevention of crimes, than others which at the same time give hope of reforming the offender,—it appears obvious, that justice and humanity alike require, that those laws which respect capital crimes, should be carefully revised, and that the punishment of death should be confined to cases, if such there be, where it is absolutely necessary for the welfare of society at large.*

2. Another and most extensive branch of justice, respects the rights of *property*. Most divisions of this head come particularly under the denomination of *honesty*. (1.) The laws of honesty of course absolutely forbid the taking away the property of others by stealth or by force; that is, they forbid theft and robbery. (2.) Honesty forbids every way of employing the property of others intrusted to us, which is inconsistent with the purposes for which it was intrusted, or contrary to the interests of those to whom it belongs. This rule of honesty clearly applies, whether the nature and extent of the trust have been formally stated or not. And executors, guardians, and trustees of every kind, are bound by it to execute faithfully the purposes of their trust, according to the obvious intention of them; and under no pretext to employ the property so intrusted to their own private use and benefit. (3.) Justice requires that we do not withhold from others their just due. This rule excludes the inhuman practice, (too common

* On this subject we beg to refer our readers to the very valuable volumes, entitled, Opinions of different Authors on the Punishment of Death, collected by Basil Montagu, Esq.; and also to the other publications originating in the Society formed in London for the purpose of diffusing information respecting capital punishments. Eventually their object must be successful; and the time may come, when the name of that great Lawyer, Sir S. Romilly, who has so long devoted himself to the cause, shall be placed, by universal suffrage, in the first class among the benefactors of humanity.

in some classes of society,) of withholding the just claims of servants or labourers; and it requires from all, the payment of their just debts at the period, when by express agreement, or common custom, they become due. He, who in such cases is content with being legally honest, has very little of the genuine spirit of integrity about him. If a man be so circumstanced that he cannot answer all the just claims upon him, he must not be guided, in his distribution of what he can pay, by the partialities of relationship or friendship, nor even by the feelings of benevolence contemplating the greater necessities of some of his creditors: if he can prevail upon others to give up some of their due, it is well; but he has no right to give away that which is not his own. (4.) Justice forbids our obtaining the property of others, (even with their consent,) on false pretences. This rule excludes borrowing money on false securities; borrowing without the means, and especially without the intention of repaying; circulating bills which have insufficient or no property to answer them; passing money or bank notes which are known to be of no current value, and all cases of a similar description. (5.) Justice forbids our employing our influence, and especially any species of artifice, in order to induce others to give or bequeath us a portion of their property, to the injury of those who are naturally or equitably entitled to it. (6.) Honesty forbids all frauds upon the public revenue; as truth also does all those which are accompanied (as most are) with false statements and declarations. Frauds of this description have had a powerful and extensive influence, in weakening moral principle and mutual confidence: and with respect to those which come under the general head of smuggling, they cannot be too much deprecated. Smuggled goods cannot be purchased, without directly encouraging fraud and falsehood in others; without assisting to train up a set of desperate persons, who are thus prepared to make society, in any way they can, their lawless prey; nor without increasing the burden of the

conscientious, and doing injury to the fair dealer. (7.) Justice requires strict uprightness in the dealings of trade; and, therefore, forbids the employment of fraudulent methods of weighing and measuring, the exposure of false samples, false representations respecting the value of articles, availing oneself of the ignorance of the purchaser to obtain more than the marketable value, the concealment of the known defects of the commodity, &c.—On several of these subdivisions, some very important and interesting information may be derived from Paley's Moral Philosophy.

3. Justice forbids all injury to the *reputation* of others. A good name is so essential to a person's usefulness, comfort, and interests, that whatever unjustly deprives him of it, is utterly inconsistent with justice. And though no one has a right to reputation for qualities which he does not possess, yet all needless, and still more all malicious endeavours to lower it, and the encouragement of others in such endeavours, should be avoided, as inconsistent with the grand rule of Christian equity, and with the dictates of benevolence, and likely to affect that degree of reputation to which the individual has a right. We owe to others great caution in forming and expressing unfavourable judgments of their conduct and character. Cases do, indeed, often occur, in which it is useful, or even necessary, to state our opinions of others; for the moral warning, for instance, of the young and inexperienced: justice then requires that we do it in such a way as shall convey a correct idea, and not lead others to form judgments beyond the truth.—It is scarcely necessary to add, that all those injurious statements and insinuations respecting the character, accomplishments, or circumstances of others, which are equally unnecessary and unfounded, whether proceeding from motives of malevolence, or from that thoughtlessness which so often produces as much mischief as malignity itself, are in direct opposition to the principles of justice as well as to those of benevolence.

4. Every one has a right to freedom of thought, and to worship God after the dictates of his conscience; and, therefore, justice forbids every thing which prevents or restrains the exercise of those rights. It is forbidden by justice, (as well as by wisdom, piety, and benevolence,) to inflict any pains or penalties upon those who adopt and profess religious opinions different from our own, on account of those opinions; and, in like manner, justice, &c. forbid us to employ any of those minor species of persecution, which tend to make it a hardship to follow the dictates of conscience.

5. Justice requires the fulfilment of our promises. By a promise, we excite an expectation in the mind of another respecting our future conduct. In proportion to the confidence he places in us, will he act upon this expectation; and cases continually occur, where it influences the plans of life. In less important cases, and, indeed, in all where promises are trusted, they do excite expectations, the non-fulfilment of which is, in different degrees, injurious to the individual, but unjust in all. Where a promise is expressed in clear and explicit terms, (as every promise should be,) it is to be interpreted in the plain and obvious sense, just as any well-informed person, knowing the situation of the parties, would interpret it. Where it is attended with ambiguity, the question should be, what expectations the promiser intentionally or at least knowingly, excited in the mind of the person to whom he made it.

Great caution should be used in making promises; they should not be made unnecessarily or thoughtlessly. And it is an important direction of moral prudence, that we make as few as possible.—If we make promises without the intention of fulfilling them, we are guilty of a breach of truth, as well as of faithfulness. They should, as much as possible, be conditional only. Where an unconditional promise is once made, we are bound by justice to fulfil it, if we can without an actual violation of duty: and where we

have placed ourselves under such obligation, nothing short of a voluntary release by the individual to whom, or for whose benefit, it was made, can annul it.—If expectations are intentionally and knowingly excited by our actions, we are under the same obligation.

6. Where we have committed injury of any kind, whether respecting the interests, the feelings, or the moral worth of others, justice requires that we do all in our power to repair it.

CHAP. XX.

REGULATION OF SOCIAL CONDUCT,

Continued.

Principle of Christian Equity—Regulation of Charity—Education of the Poor—Common Intercourses of Life—Duties arising from the Domestic Relations—Filial Duty—Obedience to the Laws—Benevolence should be influenced, supported, and guided by Religious Principle. Conclusion.

II. IN order to ascertain what justice really requires in any particular case, and to produce in our minds a steady constant sense of what is fit and equitable, it is an excellent and highly important rule, to place ourselves in the several situations of the persons concerned, and inquire what we should ourselves then desire and expect from them.

This rule is so comprehensive, that as far as respects the social duties, it may be called the sum and substance of Christian Morality. Its real object clearly is, not to define or describe justice; but to give such a criterion of social duty, as may counteract the impressions of selfishness. We seldom need fear lest we should carry our imaginary substitution to too great a length: our only danger is, lest we should not go far enough; lest we should admit of exceptions to this prin-

ciple, which, if circumstances had been real, would have had no place.

This rule of duty, says Dr. Reid, "comprehends every rule of justice, without exception. It comprehends all the relative duties, arising either from the more permanent relations of parent and child, of master and servant, of magistrate and subject, of husband and wife: or from the more transient relations of rich and poor, of buyer and seller, of debtor and creditor, of benefactor and beneficiary, of friend and enemy. It comprehends every duty of charity and humanity, and even of courtesy and good manners." "He who acts invariably by this rule, will never deviate from the principle of his duty, but from an error of judgment. And, as he feels the obligation that he and all men are under, to use the best means in his power to have his judgment well-informed in matters of duty, his errors will only be such as are invincible." (Essays on the Active Powers, Ess. v. ch. 1.)

In order to apply this rule according to the obvious intention of the great Christian Lawgiver, we are (1.) to consider, what we should wish done to us, if we were in the place of the other person, and at the same time were possessed of all the knowledge which we ourselves actually possess, respecting the object under consideration. For instance, suppose a child requests from a parent, a gratification which the parent knows would, in some way or other, be injurious to him: is the parent to grant his request, because, if in the child's place, he would himself wish to be so gratified? The answer is clear: and so in similar instances. The fact is, in all such cases we are to consider, not merely what we might wish, if so far in the situation of another, as to have all his foolish desires and his ignorance or misguided opinions; but what we should desire, with all the means of knowledge which we actually possess, and with all the views we have of the reasonableness of the objects of desire, when not ourselves under the influence of passion or interest. The rule is not so much designed to *teach* us what is just and right, as to enable us to see and

attend to what we do know; to make us think of the claims of others, and to overcome the promptings of selfishness. (2.) We must farther consider, not only what we should wish for, and, as far as respects ourselves only, might reasonably wish for, if in the place of the individual immediately concerned; but must also take into account what we should desire, if in the place of those others, whose conduct or happiness will be affected. Suppose, for instance, that a favour is requested, which, in itself considered, is right and reasonable; we might consider the application of our Saviour's rule as necessarily directing us to grant it, because, if in the situation of the individual soliciting it, we might reasonably wish for success. But it may so happen, that by attending to his request, we may deprive ourselves of the power of discharging more imperious duties to others: we may be prevented from paying our debts, or from contributing as we ought to the welfare of those who have stronger claims upon us. Their claims also must be taken into account; but we must be careful that such calculations be not made under the bias of selfishness, and that, under the pretence of justice, we do not stifle the feelings of compassion and good-will. The doublings of self-love are so numerous and intricate, that he who has the sincere and earnest desire to do his duty, will be cautious where the promptings of interest, or indolence, or other personal feelings, are concerned. "Charity begins at home," is an excellent maxim; and he who neglects his home in order to do good to others, may reasonably expect that he will do more harm by such neglect, than he can do good in other ways: but we should also remember, that this maxim is often the prompting of self-love, to excuse our covetousness or our indolence; and where the good to others is present and certain, and the good to our narrow circle of domestic relation is distant and uncertain, the latter is not to be placed in competition with the former.*

* On *Candour*, an important and perhaps too much neglected branch of justice, the reader will find an interesting passage in Mr. Stewart's Outlines.

III. Great attention should be given to the first impulses of benevolent compassion. It is well remarked by a judicious moralist, that in a mind whose moral powers have been properly cultivated, second thoughts are seldom best. The first are the impulse of well-regulated feelings, and are produced instantaneously, without attention to all the petty suggestions of selfishness, which crowd themselves in various ways into our mind, and which, by leading to doubt, and then, aided by inclination, to disobey, prevent the efficacy of benevolence and conscience, and throw a mist over the before clear directions of duty. (See Dr. Aikin's Letters to his Son.) Some, however, carry this much too far on the other side, and encourage many public mischiefs through a false, misguided tenderness to criminals, persons in distress through present vice, &c. When feeling is thus made the guide of conduct, he who can best play upon the sympathy, and best decorate his tale of woe, will meet with a reward for his ingenuity, due only to the modest merit which shrinks from the public view, or at least does not obtrude itself upon our notice. The injury done to society at large by this ill-directed compassion, (so generally prevalent, because it gratifies without trouble,) is very great indeed; and while we have it in our power to cultivate compassion and sympathy, by the view and the relief of real misery and suffering worth, the desire of such cultivation will be scarcely sufficient to exculpate us, (when our minds have acquired some degree of comprehension,) from the charge of preferring a selfish, indolent gratification, to the good of others.

Still we should grieve to see the young, in whose minds prudence has not yet been founded on benevolence, listening to its cold admonitions, and forming calculations which might excuse present, but would not prompt to future exertions: but we would aim to give their compassion that direction which would point to benevolence,—to benevolence, which should become the habit of the soul, which should be inwrought in the frame, and direct to steady exertion, when the thrilling

chords of pity cease to vibrate with their early energy. For this purpose we greatly prefer the gift of that which is their own, their activity, their time, their thought and exertion. That is the most worthy charity which is voluntary and active; "which makes itself acquainted with the object it relieves; which seems to feel, and to be proud of the bond which unites the rich with the poor; which enters into their houses, informs itself not only of their wants, but of their habits and dispositions," and "encourages with adequate relief the silent and retiring sufferer, labouring under unmerited difficulties." (Malthus.) Alms-giving is often the least part of beneficence. We should aim to see that the pecuniary gift is rendered efficacious by its direction: and often, (by means which the female sex have peculiarly in their power,) the money bestowed in alms may be increased in utility ten-fold, by the prudence and activity of those who gave it. We should give, too, kind expressions of sympathy, of attentive observance of the wants of others; we should thus link the hearts of others to us, and ours to them. It is by active exertions for the good of others, that we most cultivate our own benevolence; and, in general, it is from them we shall see most fruit.

IV. The education of the poor presents a noble field for the exercise and the culture of benevolence; and the prevalence of charity-schools in general, and of sunday-schools in particular, affords to most young persons an opportunity of engaging in it. The young should be early accustomed to consider the education of the poor, as an object of wisdom, of pleasure, and of duty. And throughout life, the diffusion of moral and religious knowledge and principle, according to our several opportunities, should be regarded as a primary direction of Christian benevolence.

Where benevolence is under the guidance of a mind enlightened in a common degree only, it will contribute its exertions to diffuse useful knowledge among the poor, and to form in their children habits of industry, order, decency, honesty, truth, and sobriety: when it is farther guided and influenced by a strong

sense of religious principle, it operates still more powerfully and extensively. It teaches us to keep constantly in view, the connexion between this life and another. It gives a value to the moral habits, far beyond their merely temporal effects, great as these undoubtedly are; and it thereby excites to more steady, and vigorous exertions to promote them, wherever we have the means and opportunity. It shews the continual importance and efficacy of those religious principles, which are, in all cases, such powerful auxiliaries to social and private duty; which are so often necessary as a safeguard and support to human frailty; and which, under the pressure of pain, of sorrow, or of want, are the only stable sources of consolation.

The general direction of benevolence to which these remarks may be referred, is, that we do whatever we can, in our own immediate circle, and in the wider circle in which our exertions and influence may be efficacious, to prevent or check vice, and its consequent evils; and that we carefully avoid whatever will destroy or weaken the moral or religious principles of others. The removal or alleviation of misery is an important object of benevolence: but the prevention of evil is still more important, and more effectual in the amount even of temporal benefit. Here no effort can be altogether thrown away; at least no effort will be prejudicial; and even if to others it should unhappily be unavailing, its effects will return to our own bosoms.

V. Benevolence directs to the habitual exercise of kindness and courtesy in the usual intercourse of life, and particularly in the domestic circle. It especially requires, that we habitually avoid every thing that will give unnecessary or excessive pain to those with whom we are in any way connected. Christian love itself sometimes calls us to adopt measures which will occasion pain to those whom we are bound to benefit; for instance, when our advice or interference may be requisite for their welfare, to prevent temporal sufferings, and above all, moral evil. And here fortitude must be exercised to overcome the influence of feeling, aimable in itself, but injurious when

it opposes the dictates of benevolence and sincerity. But benevolence has its greatest influence upon domestic happiness, by restraining whatever would give unnecessary pain, by preventing carelessness as to the peace and comforts of those around us.

Many whose feelings are ardent, and who really possess the desire of doing good, seem to think that beneficence affords the principal scope for the exercise of benevolence; forgetting that he does great good who abstains from all harm. They would gladly exert themselves to confer some great benefit on their fellow men; but forget that the sum total of good derived from the daily endeavour to avoid injury, may be, and often is, much greater than could be produced by a great and strenuous effort to do good. Carelessness respecting the feelings of those around us, in the smaller offices of kindness, may be supposed to produce only a momentary uneasiness, or at least a momentary pang: yet how much the sum of those moments affects the happiness of life, let those say, who have seen, or who have felt, the nearest connexions embittered by them; who have observed filial affection checked at its bud, by needless or even selfish harshness on the part of the parent; or, what is much more common, the care, the tenderness, the exertions of the parent, repaid by the cold reply, the negligent or even disrespectful air, and numerous other little circumstances which are deeply felt, but can scarcely be described, arising from the want of an honest desire to avoid every cause of painful emotion to those to whom so much attention and kind respect is due: or let those say, who have observed that relation which was designed, and is fitted, to be an important means in raising the mind from self, and giving it a lively interest in the welfare of others, made, as it so often is, a source of mutual suffering. Those whose minds are formed to give and to receive happiness, have often lost the power of both, by neglecting a due restraint upon the irregularities of their dispositions, by want of the actuating desire to avoid all needless causes of uneasiness and pain: and those have

often been involved in similar, and equally lasting, though not perhaps equally acute distress, who with a little care, and a little check upon the roughness of temper, and even common attention to the feelings of those around them, might have passed along in the journey of life at least with tranquillity.

View the subject as we will, so many of the more constantly occurring distresses of life, obviously arise from the want of the sincere desire to do injury to no one, that it seems as if what is most wanting for an extensive diffusion of human happiness, is, that every one should permit others to be happy if they can.

Nevertheless, to avoid error, we must add, that careful abstinence from all kinds of injury to others, where it springs from genuine benevolence, will never be unaccompanied with the sincere and effectual desire to do good, as opportunity offers. A truly inoffensive life, will be a benevolent life.

VI. Benevolence peculiarly requires a careful attention to the duties resulting from the more limited relations of social life. To enter into the consideration of those duties, would here be impracticable. The attentive reader, however, even if possessed of but little experience in life, and little acquaintance with ethics, will be well prepared to pursue them for himself, by the principles already laid down. What we have here in view, is an illustration of the general position, which we shall follow with a few hints respecting the filial duties.

About five and twenty years ago, in that great moral tempest which succeeded the French Revolution, it was maintained by some, who were more influenced by the ardour of speculation and a fondness for brilliant paradoxes, than guided by that cautious and patient sobriety of mind which we should ever exercise on subjects connected with the moral welfare of mankind, (and others of less ability fell into the same error,) that what are termed the confined charities of life, must always be sacrificed to what they called the public good; and that universal benevolence should be our object, without

respect to the supposed claims of the nearer relations of household or kindred, friendship, gratitude, or affection. "It is not our business in the direction of our benevolent exertion, (to use the words of the leading writer who publicly supported this opinion,) to consider the relation in which the individual stands to us, but that in which he stands to society: not, is he *my* parent, relative, friend, or benefactor, but is he a worthy or worthless member of society?" He puts the case, that the palace of the excellent Fenelon had been in flames, and that it was impossible to save both Fenelon and his servant, but that one might be preserved by my exertions:—that servant might be my son, my father, or my brother: shall I therefore save him in preference to Fenelon, whose life must be much more valuable to the world? Justice, pure and unadulterated justice, (said Godwin) would prefer the life of Fenelon.

Upon the same principle, if my wife, my child, or my parent is, with many others, sinking in the waves, I am not to rescue the one whom nature prompts me to rescue at all risks, if I have reason to believe that some other, whom I might save instead, is of more service to society. In such a dreadful alternative, however, few would hesitate in believing that the voice of nature is the voice of God.

The principles we have referred to, were neither founded in that nature which the wise Author of our frame has given us, nor in the actual condition of humanity: nor are they really consistent with the welfare of society. Their direct tendency is to loosen the bonds which bind man to man. *All* men would never be loved, if we never loved *some:* and even if some uncommon case occurred, in which *universal* benevolence prompted as a steady principle of action, without the influence of the more limited charities, they would be too rare to carry on the good work which the Universal Parent has given man to do for his fellow men.—Besides, if we were always to be determined in our benevolent exertions, (both extraordinary, and of constant occurrence, and particularly in

cases of immediate urgency,) merely by the consideration of the usefulness of the individual to society, our lives would be a continual series of calculation; and, in general, of erroneous calculation. Who is there capable of estimating the worth and usefulness of each one with whom he is concerned, with complete accuracy? and what two persons could in general agree in their estimate, so as to co-operate with one another?—And once more, is it not in our own circle that we may do most good by our exertions, by our instructions, by our example? Is it not there, in general, that we can see best what is to be done for the good of others, and how it is to be done? More good is commonly to be effected by the faithful upright discharge of the duties of a man's nearer relations in life, than by his neglecting those duties from the idea of doing good in a wider sphere. And if so, those principles must be radically erroneous, which would lead us to annihilate the efficacy of those more limited charities.

The domestic and relative charities are undoubtedly capable of being greatly perverted. The parental affections, *e. g.* may degenerate into foolish capricious fondness, alike destructive of the parent's happiness, and the welfare of the child: They may be allowed unnecessarily to limit or check the exercise of benevolence. Nevertheless they form an essential and most important part of our nature. They rise up in the human heart, without our care, and almost without our knowledge. They are some of the most powerful springs of action; and often lead to the most disinterested exertions. They are the root of general benevolence; and their numerous fibres contribute to draw off from self-love, those juices which would otherwise feed the wide spreading shoots of selfishness, whose noxious influence sometimes poisons the sources of individual worth and domestic happiness. They are in fact the basis on which the whole structure of benevolence and piety is most commonly raised.—The duties arising from the nearer relations of life, are therefore of the utmost importance: and if you can truly say that a man is, in the just sense of the term, a *good* husband, a *good* father, a *good* son,

a *good* brother, you may infer, with very little hesitation, that he is a man in whom moral and religious principle has taken deep root, and may look to him for great stability and worth of character in general.

VII. The duties of the *filial relation*, like all others which respect the connexions of social life, may, with great advantage, be derived from the grand principle of equity, already considered. As, however, in the early periods of life, it is impossible for a child to enter fully into the views and feelings of the parental relation, it is best that obedience and kind behaviour should be the result of simple and habitual affection, of gratitude for obvious benefits continually and daily conferred, and of an evident and tender concern to do them good. But when the period arrives in which restraint, even the most wise and tender, often becomes irksome, and the sanguine hopes and eagerness of youth make the sober caution of experience appear like timidity, then the great rule of benevolent equity will be of eminent service, where there is any proper principle to excite to the employment of it.

By it the young would be led to attend to the too often forgotten consideration, what return parental solicitude and exertion demand. They would place themselves in the situation of their parents: and reflecting upon the tender care which year after year had been employed to do them good, the disturbed nights and anxious days which their infancy had caused, the continual privations, the constant earnest efforts of succeeding years, made to promote their pleasures and their welfare,—they would consider whether, in such circumstances, they should not themselves justly expect to be treated with kindness and attention, to meet with at least uniform civility, and a ready compliance with their wishes, even where the reasons for them were not perceived or mentioned. They would then be led to perceive, that the judgment of their parents should be of great weight with them, where they are themselves to decide as to their actions or plans of life; and that they owe them cheerful submission where their parents

are to decide for them. And they would then, too, be led to perceive how much they owe it to their parents to keep aloof from those criminal courses which would inflict incurable wounds in their hearts.

Even where there are many and obvious faults on the part of the parents, still the young should bear in mind that they too have had many and great faults; and that if their parents had, on account of them, been inattentive to their wants and wishes, their comforts would have undergone a great diminution; and that however numerous parental errors are, yet also to them there have been many and great benefits.

Cases too occur, in which parents become, in some measure, dependent upon their children, for the continuance of their comforts, perhaps even of their means of subsistence; and their children are in a particular manner called upon, (if filial affection do not render it unnecessary,) to consider what would be their own reasonable expectations, were they in the place of their parents; and what they certainly will be, should they ever be themselves so situated with respect to their own children. And if any cases occur, (which, however, are not frequent among the wise and good,) that children, when arrived at the years of discretion, are called upon, by a sense of duty, to act in decided opposition to the wishes and authority of their parents, attention to these principles will render their opposition mild and forbearing, so as to lessen as much as possible the pain which they will at any rate occasion.

Such considerations will be found of eminent utility to those in whose minds the filial affections have not acquired their full vigour; or who, from unhappy peculiarities in their parent's disposition, may have frequent call for the exercise of mildness and forbearance. But where the mind of a young person is rightly imbued with those affections, their natural promptings, aided as they will ever be, in the well-disposed mind, by the dictates of duty and general benevolence, will almost always so guide the conduct as to coincide with the wishes of the wisely affectionate parent.

VIII. Obedience to the civil magistrate, and to the laws of the community, is a subordinate general rule of the greatest importance. It is evidently for the public good, that every member of a state should submit to the governing power, whatever that be. Peace, order, and harmony, result from this, taken in the whole: confusion and mischief of all kinds from the contrary. So that, though it may reasonably be supposed, that disobedience in certain particular cases will, as far as the single act and its immediate consequences are considered, contribute more to the public good than obedience, yet as it is a dangerous example to others, and will probably lead the person himself into other instances of disobedience afterwards, disobedience becomes, in every case, upon the whole, of a tendency destructive of the public welfare. We ought, therefore, in consequence of this rule, to pay proper respect to all persons in authority; to observe the laws ourselves, and to promote the observance of them where the penalties may be evaded, or are found insufficient; to look upon property as a thing absolutely determined by the laws, so that, though a man may, and ought to recede from what the law would give him, out of compassion, generosity, love of peace, view of greater good upon the whole, &c., yet he must never in any way evade, strain, or do violence to the laws, in order to obtain what he may think his own according to equity; and whenever he has offended, or is judged by lawful authority to have offended, he must submit to the punishment whatever it be.—(See Hartley's Rule of Life).

This rule obviously does not extend to those extreme cases, where the people at large, (for whose benefit all power should be exercised, and on whose will it must eventually depend,) see reason to resist the exercise of usurped or arbitrary power, to change one line of sovereigns for another, or to place the existing monarch under those restrictions which may prevent the abuse of his authority. In making such resistance, however, it ought to be perfectly clear, that the proposed change will meet with at least the concurrence of the great

bulk of the people; that the probabilities of success are adequate to justify the risks which must be run; and that the advantages to be gained will be such as to counterbalance the immediate evils,—evils which must often check the ardour of enlightened and disinterested patriotism, and should be seriously weighed, not only in the more extensive cases, but even in those which merely respect the reformation of real or supposed abuses. The mass of suffering and of moral evil produced, where force must be employed to throw off an oppressive yoke, is utterly incalculable; and, on the whole, more is generally to be effected by the gradual diffusion of knowledge, and of sound views of the nature and ends of political establishments, which must eventually, (and often much more rapidly than could be expected before-hand,) set a complete bar to all injurious encroachments on civil liberty.

Nor does this rule extend to those important cases where the rights of conscience are concerned. If the laws of the civil magistrate require any thing which the law of God forbids, we must, without hesitation, obey God rather than Man.

Our readers will, throughout, have perceived our desire to rest our moral system upon religious principle; and we may add here, that we regard piety as the best foundation and surest support of benevolence. The origin of benevolence, in the order of nature, precedes that of piety; and benevolence does sometimes, without the direct aid of piety, acquire a high degree of disinterestedness, steadiness, and vigour. But, as a general fact, there can be no hesitation in affirming, that without the influence of piety, benevolence will be an unstable, irregular principle of action; and that where it has the support and encouragement and direction of Christian piety, its purity, vigour, and firmness, will be materially increased, its influence on personal happiness greatly heightened, and the sphere of its operation widely and most beneficially extended.

As long as human sympathy and encouragement are ne-

cessary to the warmth and activity of benevolence, as long as it depends upon the pleasures of *perceived* success, as long as ingratitude and disappointment have power to cool its energy, it will be wavering and uncertain. But place it under the direction of piety, let it be influenced by its views and principles, let it possess its hopes and encouragements, and it will go on with consistency in the work of duty. The influence of those obstacles will less be felt, which sometimes almost destroy the disposition to benevolent exertion. The disappointments of benevolence will lose much of their poignancy, when regarded as a part of moral discipline; and viewed in their connexion with the general dealings of providence, they will even serve to give it a more prudent and more useful direction. And pious benevolence will always find opportunity for its own exercise, in restraining the promptings of selfishness, in rooting out all malice and ill-will, in promoting the temporal comforts of those around us, in endeavouring to relieve their distresses, and above all, in promoting their eternal welfare. And there its labours cannot be in vain.

Advice to the Student.

As we have already stated, our object in the foregoing sketch has been, to give that direction in the pursuit of Moral Philosophy, which will make the study of it thoroughly beneficial. There is no branch of knowledge in which it is of more importance to set out well. The whole moral system will be affected by the principles upon which we rest as its basis. And those who have experienced the perplexities which incorrect or partial views of moral science can scarcely fail to produce, will not wonder at our solicitude, to assist our readers in adopting those which can do them nothing but good, and which, pursued with prudence and good sense, will be eminently serviceable in the whole round of moral investigation, and in the whole course of moral practice. We trust that to those who possess habits of thought and reflection, our aid will be of real value.

We should recommend to those who have hitherto paid little attention to the subject, to give a second perusal to the preceding chapters before they proceed to other works, for which they will then be well prepared. Some we have referred to as we went along; and the reader may find it advantageous to consult those references in the appropriate places. But he will not of course wish to defer too long the study of *Paley's Moral Philosophy*. Its merits are truly great; and it is the more to be regretted, that this eminently useful writer had not habituated himself to greater accuracy and precision; and, above all, that he had not adopted a more unexceptionable theory of morals. He has enlivened and familiarized his subject, perhaps beyond example: he has made really profound investigations often appear simple and even attractive: he has employed Christian sanctions and Christian principles, before too much neglected by the moral philosopher: and his morality is, in general, sound and comprehensive; and the explication of it alike interesting and impressive. The peculiar merits of the work are delineated, in Paley's most happy manner, in his Preface; and if the student first peruse that, he cannot fail to go with interest to the rest of the volume. Notwithstanding all the real excellencies of the work, however, his system is, in our opinion, fundamentally erroneous; and this error in the basis, has, in some important cases, led the author himself to erroneous conclusions, and has still more produced this effect among his readers.

In connexion with Paley, we most strongly recommend the study of *Pearson's Remarks on the Theory of Morals*, and his *Annotations on the practical part of Paley's Moral Philosophy*. The Annotations extend only to the first volume; and it is much to be regretted that the author has not yet fulfilled his promise of presenting the Public with a second part.—The reader may also derive considerable benefit from the perusal of a work of real value, though of less eminence, viz. *Gisborne's Principles of Moral Philosophy*.

We trust we have already said enough to lead our readers to the study of *Hartley's Rule of Life;* and with it we strongly recommend to their perusal two sermons by *Dr. Priestley,* on *Habitual Devotion,* and the *Duty of not living to Ourselves,* which may be found in a small volume entitled Sermons by Dr. Price and Dr. Priestley.

After this, we know no reason why any particular order should be adopted. Those works or parts of works may be read, to which the course of study, or accidental circumstances, direct the reader's attention. Respecting the ancient systems of morals, *Enfield's History* will give him much information. If he wish to enter farther than we have done, into the theory of morals, he will find sufficient references in *Belsham's Elements;* and in *Kippis's Edition of Doddridge's Lectures,* he may obtain abundant direction to the best sources of information on practical morality. Among the references given by Doddridge and Kippis, he will find many to Sermons; and from the productions of some of our most judicious divines, a complete and excellent system of morality might easily be formed. In this view we may mention the Sermons of Barrow, Tillotson, Secker, Jortin, Foster, Seed, Clarke, and Leechman, as affording copious sources of moral information.

Dr. Cogan's Treatises on the Passions, deserve to be particularly studied in connexion with moral, as well as with mental philosophy; and though the writer of these chapters has had no opportunity of peruing Dr. Cogan's late work on the theory of morals, he has no doubt that it will well reward the study of the philosophical inquirer.

Much solid information will be found in *Reid's Essays on the Active Powers,* connected with practical morality. And we should be inexcusable if we did not refer those of our readers who are interested in moral investigation, and are accustomed to close thought, to *Dr. Price's Review of the principal Questions and Difficulties on Morals,* and to *Bishop Butler's Works.* The study of such writers can scarcely fail to make a man wiser and better.

LOGIC.

CHAP. XXI.

IDEAS, WORDS, CLASSIFICATION, AND DEFINITION.

Object—Division—Sources of Ideas—Simple Ideas—Complex Ideas—Substance—Modes—Simple—Mixed—Ideas of Relation—Importance of the Knowledge of Words—Sources of Names—Etymology—Ambiguity—Modes of conveying the Import of Words—Classification—Species—Genus—Arrangement of the Naturalist—Specific Difference—Comprehension—Extension—Predicables—Categories—Definition—Properties of a good Definition—Maxims respecting the Use of Words.

THE Art of Logic is a system of rules and observations, by which the understanding is directed in the ascertainment of truth, and the communication of it to others.

It is evident that the foundation of Logic must be laid in the principles of the human understanding; and the Theory of Logic must, therefore, comprehend the investigation of those principles. It is on this account that we thought it best to

defer the present division of our work, till we had laid before our readers an outline of Mental Philosophy. And, though we shall not presume upon a complete acquaintance with the chapters relating to that science, yet they certainly will find it of great advantage in the judicious study of Logic. If, however, they are disposed to invert the order here adopted, and begin with Logic, we hope they will find this division intelligible, without further attention to the foregoing than what our references may require.

Logic is sometimes represented as the art of reasoning: but reasoning is only one of the operations of the understanding; and, taking the logical acceptation of the term, it is not the most important.

A large proportion of the technical terms and distinctions of the Logician, are of very little value; and they would scarcely deserve attention, were they not occasionally referred to in the writings of those who have been familiarized with them in the schools. Our object will be, to introduce our readers to an acquaintance with such as may, in some way or other, be of real utility; and to aid them in acquiring those principles, which may assist them in the proper use of their intellectual powers.

Logic is commonly divided into four parts: (1.) *Perception*, comprehending all that respects our *ideas*, without reference to the operations of judgment and reasoning, by which they may in part have been formed: (2.) *Judgment*, which respects those decisions of the understanding, which arise from the comparison of the objects of thought: (3.) *Reasoning*, which includes those operations of the mind, by which the relation betweeen two objects of thought is inferred from their mutual relation to another: and (4.) *Arrangement*, or *Method*, which has for its object, the disposal and arrangement of our thoughts in that order which will best display their mutual connexion and dependence.

Some writers on Logic omit the last division; considering it as conveniently falling under the head of Reasoning. The

fact is, the operations of the understanding are so complex, and so intimately connected one with another, that it is not always easy to discriminate them. It is not, however, of great consequence to our present purpose, to enter into any nice discussion of these points; but to avoid communicating any erroneous ideas respecting the processes of the mind, we shall adopt a division less scientific in form, but which will better answer the leading object already stated. We shall, therefore, arrange this part of our work under the following heads: *Ideas*, *Words*, *Classification* and *Definition*, *Propositions*, *Evidence*; *Syllogisms* and *Sophisms*; *Observations on the Pursuit of Truth*.

Ideas.

According to the views which we have already endeavoured to convey to our readers, our ideas (with the exception of those of reflection,) are the relics of sensation, variously combined by the operation of the associative power, and modified, in different ways, by the exercise of the understanding. And to avoid unnecessary repetition, we shall presume upon our readers here re-perusing what we have said (p. 249-251) on the distinctions of ideas as founded on the laws of association; and proceed to add a few observations respecting Mr. Locke's phraseology, which was framed before the operations of the associative power in the formation of ideas had been investigated, but which still is most commonly adopted by the writers on Logic.

Mr. Locke supposes all our ideas to be derived either from sensation or from reflection; and that these are, with infinite variety, compounded and enlarged by the understanding. So far, apparently without any acquaintance with the compounding influence of association, that great philosopher had proceeded; and in this view he is undoubtedly borne out by all that is known of the operations of the mind.

The term *simple idea*, in Mr. Locke's nomenclature, is applied to all ideas which we cannot consider as made up of

parts. Such for instance are, (1.) the ideas of *light* and *colours, sounds, tastes* and *smells,* of *heat* and *cold*, and *solidity;* and (2.) those of *extension, figure, rest, motion,* &c. Some of these are derived from one sense alone; the second class from more than one sense.

Now a very slight acquaintance with the actual formation of our ideas, will convince any one, that the denomination *simple idea* must not be considered as referring to the ideas themselves, but to the qualities which are the objects of them, and from which they are derived. Our notion of *solidity,* for example, so far from being a simple idea, in the strict sense of the term, is derived from a vast number of impressions, producing the sensation which we experience when a solid body is applied to the sense of feeling. The notion of *figure* is still more complex, being derived not only from a number of sensations, but also from such as vary greatly from one another. The idea of a particular plain figure, may be a simple idea; but the notion connected with the word *figure,* is extremely complex. When, therefore, in Mr. Locke's language, we speak of simple ideas, we are not to understand the word *simple* as expressive of the simplicity of the ideas themselves, and implying that they are elementary ideas, (derived from single sensations through one sense,) but as referring to the simplicity of the qualities of which they are the ideas. We cannot conceive or think of *solidity* as a divisible quality; and the idea of solidity may, therefore, be termed a simple idea.

In this application of the term, there may be *simple ideas of reflection* as well as of *sensation;* such as those connected with the words *volition, feeling, recollection,* &c. These operations or states of mind, are simple, and, therefore, the ideas of them may be called simple; though there is no doubt that each of these is formed from numerous impressions produced by attention to the corresponding states or operations.

Following the same method of classification, Mr. Locke

calls those ideas *complex*, (without reference to their being composed of elementary simple ideas,) which are derived from objects capable of being represented to the mind as compounded of different parts or qualities. For example, the idea of an *army* he considers as complex, (not because the notion affixed to the term is derived from a variety of impressions in connexion with it, made either through direct observation, or by oral communication,) but because we can consider an army as made up of parts. He does, however, employ this term much more widely, to denote all ideas which are derived from any operation of the intellect, except the simple ones of sensation and reflection : and though it appears, from the theory of association, that he was sometimes mistaken as to the nature of complex ideas, yet his use of the term on the whole sufficiently corresponds with the Hartleyan acceptation of it.

The mind is in some sense passive, in the reception of simple ideas ; its attention of course is requisite, but this is all. When the attention is given to the object from which they are derived, it cannot exclude or change them. They may be recalled by various associated ideas ; but they cannot be communicated to any one who has not had the external or internal impressions by which they were produced. To endeavour to convey to a blind man a conception of *colour*, to a deaf man an idea of *sound*, or to a person who never reflected on what passes within him, an idea of the act of *judging*, would be perfectly useless.

Complex ideas may be conveyed, where the simple ideas composing them have been received. And it is the object of definition, or description, to produce in the mind of the hearer the notions or conceptions which are in the mind of the speaker.

Though the elementary ideas which enter into complex ideas, must have been derived from sensation or reflection, yet many of the combinations of them formed by the operations of the mind, have no *archetype*, or real existence correspond-

ing to them. Complex ideas are, therefore, of two classes; those derived from actual sensation or reflection; and those which are formed by the exercises of the imagination and understanding.

All the objects of the understanding are properties, or separate collections of properties; and when these last exist in the same common subject, connected together by some unknown bond of union, they are denominated *substances.* All we know of substances is their properties; but the imagination can scarcely rest, without resorting to some support or substratum of those properties; to which the appellation *substance* is peculiarly appropriated. *Body* or *matter* is an extended resisting substance; *Spirit* is a thinking substance. The *real essence* of any material substance is that peculiar structure of its constituent parts, on which its properties depend. Of this we know nothing more than that as the resulting properties are different, the real essences must themselves be different. The *nominal essence* is that collection of properties from which our notions of it are derived, and which the name given to it denotes.

The qualities or properties by which substances are distinguished from each other, or the ideas of them, are called *Modes* (i. e. the manner of being). If these properties are supposed to be inseparable from the substance to which they belong, they are called *Essential Modes;* if experience or analogy teach that they are not thus inseparable, they are called *Accidental.* Thus *extension* is an *essential* property of a stone; *roundness* is only *accidental.*

When the ideas of modes are obtained merely by the combination of the same simple idea, they are called *Simple Modes.* Thus the addition of unity to itself, forms all the varieties of number; and the idea of a *dozen,* a *score,* &c. is called a simple mode; and in like manner the ideas of *extension* and *duration* are called simple modes. When, on the other hand, they are formed by the combination of ideas of *different* kinds, they are termed *Mixed Modes;* such as those of *beauty,*

parricide, &c.—Another class of ideas consists of those derived from the mutual connexions, dependence, and correspondence, which exist among the various objects of thought and perception. These are *Ideas of Relation.* They are of the highest importance; the duties of life depend upon the relations which moral agents sustain towards each other. Ideas of relation may be clear, though the subjects of those relations are very imperfectly known.

Words, Classification, Definition.

Words are essentially necessary to most of those grand intellectual operations, which are accomplished by the direct or indirect agency of the associative power; and they contribute in a most powerful degree, to the extent, and correctness, and proper direction of all which respect the affections. On the right use of words depend, in an almost incalculable degree, the improvement and proper direction of our intellectual and moral principles, and our influence on the happiness and worth of those around us.

At no very remote period it was common to decry the attention which is given, in every system of liberal education, to the acquisition of verbal knowledge; and there can be little doubt that it is, in a variety of instances, carried to an extreme. The knowledge of *things* should certainly go along with knowledge respecting the *signs* of things, and of our ideas respecting them: but those who have observed the varied ways, in which a well-conducted classical education calls into exercise the power of discrimination,—how greatly it contributes to produce accuracy in the use of words, and consequent correctness and distinctness of ideas,—how much, in short it cultivates and improves those qualities of the understanding, which are continually requisite in the usual employments of life,—will not readily relinquish the opinion, that no intellectual pursuits which are adapted to the early periods of intellectual culture, can fully supply the want of it.

Words become connected with ideas, solely by association,

and the theory of association is of the utmost importance in all our investigations respecting language. Those who are familiar with the operations of this principle, will easily understand its influence in the various changes and modifications which take place in the meaning and employment of words. We must presume upon our readers' acquaintance with what we have already stated on this subject, (see p. 301-308,) and shall here proceed to offer them some remarks of a more directly practical nature.

Though language is so necessary to individual and social improvement and happiness, disadvantages attend it which in the present condition of human nature it is impossible to avoid. Perhaps they never can be altogether avoided, on account of the constant progress of knowledge, and the ever-varying influence of external objects, producing continual changes in opinions, customs, &c.; but they may be greatly lessened by proper attention to the correct use of words.

There are three ways in which names may be given to new combinations or modifications of ideas: (1.) By the formation of names altogether new: (2.) By the combination of old words: (3.) By the extension of a term already in use, belonging to some other object of thought, having a real or supposed resemblance, correspondence, or relation, to that for which the name is requisite. The first method is suited only to the early progress of language: the second is the origin of numerous words in every language that is at all copious; and from it arise all the varieties of flexion: the third is that which, from the difficulty often attendant upon the second, will usually be found most suited to natural exigencies, and is most commonly adopted in practice. In many instances this extension depends upon arbitrary, and sometimes upon ill-founded associations; and it frequently is not easy to trace the causes of it.

Where words have undergone little change from their original signification, (as in numerous terms of art and science,) etymology is of great advantage in tracing out their import;

and it supplies a useful check upon the changes which might otherwise take place in the appropriation of them. But with respect to words in common use, even where the etymological signification is still apparent, it not unfrequently affords but little guidance in determining their present import. This will be found particularly applicable to all those words of common occurrence, which relate to mind and its operations; such as *understanding*, *invention*, *taste*, &c.—We would not, however, be understood to discourage a habit of tracing out the etymology of words; but on the contrary, we strongly recommend it, as a valuable means of cultivating that attention to them and their import, from which very beneficial results may be expected, both in the proper use of them, and in the various exercises of the judgment which relate to them.

It is from the gradual, and often imperceptible changes in the application and meaning of words, and from the extreme difficulty of so limiting their application in any particular cases, that they may convey to the reader or hearer nothing more than we wish to convey, that the grand difficulties arise in reasoning, and in the reception and communication of knowledge.* And it is from unobserved associations, connected with the processes of the understanding or the feelings, that words the best defined, are often incorrectly employed, or, however correctly employed, do not convey to others the ideas with which they are properly associated in our own minds. This is the case with all those terms which do not denote sensible objects; and, in particular, with those which denote relations that cannot be precisely defined, and the ideas of which are only to be acquired by gradual use.

One common source of ambiguity, is the various extent in which the same word is employed. For instance; *virtue* is

* Connected with these remarks, we recommend to our readers some observations on the word *bishop*, in Dr. Watts's Logic (I. iv. 2): and in the following sections of that valuable work, they will find many statements and examples respecting the distinctions of words, which may prove of considerable service to them.

sometimes used in a kind of contradistinction to *piety*, referring merely to the *social* and *personal* duties: in other instances it is clearly used to include every branch of duty. In like manner, some employ the term *morality* in reference to the regulation of the *external* conduct, by the rules of *social* and *private* virtue: others extend it to the *whole* of duty, and make it include the affections and dispositions from which the conduct springs.

Ambiguity is sometimes occasioned by the use of words in a figurative sense,—when they are employed to denote objects which only bear some real or supposed *correspondence*, *relation*, or *resemblance* to those which were originally intended by the words. Though this change of meaning however, is extremely common, (and indeed much of the beauty and impressiveness of language depends upon it,) yet it seldom produces obscurity. It is usually obvious in what way the word is employed; and in a vast variety of instances, that which in strictness must be termed the figurative sense is become so familiar, that the plain original meaning is entirely forgotten. This is peculiarly the case with those words which have been transferred from objects of sense, or bodily qualities or actions, to those of intellect or affection: such for instance as *virtue*, *spirit*, *ambition*, &c. And it often happens, that words which in their native language were figurative, when transplanted into another, have only that import, (or one analogous to it,) which they had acquired, when the change of soil took place: such for instance, is the word *sublime*, the universal import of which, in our language, throughout all its applications, has no reference to its original meaning, *under* (or *from under*) *the mud.*

Though, however, little or no ambiguity is produced by the figurative use of words, where that is common and familiar, yet it not unfrequently happens, that the figures of one language, when transplanted into another, are productive of considerable obscurity. It is not always easy to ascertain the precise degree in which the figurative use has been employed;

and this is peculiarly the case with respect to those compositions, which are the offspring of remote ages, and which originated among nations whose customs, and modes of thought and feeling, greatly differed from our own.

The ambiguities of language have the greatest influence in all those cases where the passions and affections are in any way concerned. Were it not for the efficacy of these in warping, or even blinding the judgment, it would commonly be easy to distinguish the meaning of others, and to communicate our own ideas intelligibly. And it is a great advantage of attention to the different causes of ambiguity, (for which we must refer the reader to Watts's Logic, I. iv. 7, 8.) that it leads us to make more allowances for the errors of others, and to use greater caution and precision in the statement of what we suppose to be truth.

We are not here concerned with the modes of arousing the affections, and producing a deep impression on the mind, but with the pursuit and communication of truth; in other words, with the exercise of the understanding. And for this important purpose, nothing is more important than the habit of discrimination, (see p. 311;) and this has a wide field for its most serviceable employment, in the ascertaining of the import of words, and the careful employment of them according to their import. The habit early formed, of accuracy in the use of words, is of incalculable service through life.

Besides the direct reference to the thing signified, there are three modes by which the sense of a word may be conveyed: (1.) By shewing how it is used in different intelligible combinations, without attempting any explanation of the word itself: (2.) By explaining it by some other equivalent word or combination of words which is more familiar to the mind: (3.) By *definition*, properly so called, in which those parts or properties of the object are stated, which distinguish it from all others. The first is continually employed in the early periods of culture, (see p. 307.) It is the way in which, by association, the meaning of most words is then learnt; and it shews us how

gradually the proper import of words is acquired, and how much the force of them must differ, in proportion to the opportunities of perceiving their force. The second pretty much corresponds with what Logicians call the *Definition of the Name.* The third is denominated the *Definition of the Thing.*

An acquaintance with the CLASSIFICATION of the objects of human thought, is of great importance in the business of definition, as well as in some of the highest exercises of the understanding. And though it is by no means necessary to be continually employing the technical terms of the Logician, in order to denote our divisions and subdivisions, yet the method itself is of great and constant benefit.

By comparing together a number of individuals, or distinct objects of thought or perception, we observe, that though they differ from one another, they agree in certain particulars: we accordingly class them together, and call the collection or class a *Species.* On comparing several of these species with each other, we find, that though distinguishable from each other, they have certain points of resemblance: and those species which possess this resemblance, are classed together, and form a higher collection, called a *Genus.* The name of the species includes the characteristics of the genus, and also the distinguishing peculiarities of the species. That of the genus includes the former, but has no reference to the latter.

It is obvious, that this classification may be made rapidly, by selecting only a few common properties, and making the genera extensive, so as to include a great number of species; or we may divide and subdivide as long as there are common properties in which a small number of individuals, or of species agree.

When several genera are classed together, as agreeing in some common properties, they are considered as forming a *Superior Genus;* and of these superior genera, a still higher may be formed; and so on till we come to that which includes all subordinate genera, and is itself included by none. This is

called by the Logician, *Genus Generalissimum.* Descending again from the genus generalissimum, we find that a higher genus includes several subordinate or *Inferior Genera;* and each of these may include others, and so on till we come to the lowest collection, namely, that of individuals. Now, as in the lowest branch of classification, a genus includes several species, each inferior genus is considered as a species, in reference to that next above; and the lowest rank in the classification is sometimes called *Species Specialissima.*

That genus which in the scale of classification is next above any species or genus, is called the *Proximate Genus;* and that species which in the descending scale is next below, is called the *Proximate Species.*

The modern Naturalist, in his classification, finds it expedient to adopt more terms than genus and species. With genus generalissimum he has of course nothing to do; and the term species specialissima is, at best, but a clumsy addition to the arrangement. This is therefore generally discarded. The system itself, however, is of the utmost importance; and it is one grand object of the Naturalist, to classify the various tribes of living beings, with which his examination into the works of nature makes him acquainted. We may add, that it is one great use of Natural History, particularly in the early progress of mental culture, that it familiarizes to distinct arrangement: and though the order of nature often defies the discriminative power of the Naturalist, yet his classication, where wisely constructed, is fully borne out, in most of its parts, by natural distinctions.

To take the descending scale. All the objects of Natural History are, in the first place, arranged under three grand divisions, which are sometimes termed the three Kingdoms of Nature. Taking one of these, (the Animal, for instance,) it is first divided into several *Classes*, such as Quadrupeds, Birds, Fishes, Insects, &c. Then each class is divided into various *Orders;* the Class of Quadrupeds for instance, into Hoofed, Digitated, &c.; or into Bruta, Feræ, &c. Each Order, say

the Hoofed, is next divided into different *Tribes*, or *Genera*; the Horse Tribe, the Ox Tribe, &c. Next the *Genus* (Horse) is subdivided into several *Species:* Horse, Ass, Zebra, &c. And of the *Species* (Horse) there are several *Varieties*, such as Arabian Horse, Hunter, Racer, &c. And each of these Varieties includes many *Individuals*.

Now if the Species be *Zebra*, the Genus is *Horse;* the Proximate Genus is *Hoofed Quadruped;* the next higher, is *Quadruped;* the next is *Animal;* and the highest, or Genus Generalissimum, is *Being*. With respect to *Animal*, *Quadruped* may be termed Species; and so in the other cases: but this is obviously a less perfect nomenclature than that of the Naturalist.

That property, or collection of properties, by which a species is distinguished from all other species under the same genus, is called the *Specific Difference*; and in like manner the properties which distinguish the genus from all other genera under the same order or superior genus, is the *Generic Difference*.—Thus the *species* Horse is distinguished from the other species of the horse tribe, by its *long flowing mane*, and *bushy tail covered with long hairs;* and these circumstances constitute its Specific Difference. The *genus* Horse is distinguished from all other hoofed animals, by its being *whole-hoofed;* this constitutes its Generic Difference.

The *Numerical Difference* is that collection of properties which distinguish the *individual* from all other individuals under the same species: thus the properties of *time, place, rank, figure, character, actions*, and other incidents, distinguish one man from another.*

The *Comprehension* of a general term refers to the properties or circumstances which it comprehends; the *Extension* of it refers to the number of individuals to which it is applicable: the greater the comprehension therefore, the less the

* Genus, Species, Difference, Property, and Accident, were termed by the older Logicians the *Five Predicables;* because, said they, whatever is predicated or affirmed of any subject, must be one or other of these.

extension; and vice versa. Thus the term *being*, comprehends only the single idea of existence; but it extends to an infinite number of individuals. On the other hand, the term *quadruped* extends to a much smaller number of individuals; but it includes the circumstance, that the being to which it is applicable is an animal having four legs.

The habit of correct arrangement in reference to the various objects of thought, is of incalculable service in every department of science; and it greatly contributes, not only to the successful pursuit of knowledge, both physical and mental, but to the beneficial communication of it to others. And it may reasonably be admitted, that notwithstanding all the absurd and endless distinctions to which they have led the Logician, the art of Logic has done infinitely more for science by its principles of classification, than by its syllogistic subtleties.

That this fondness for arrangement was however carried to a wild excess, is obvious from Aristotle's attempt to class all the objects of human thought under ten heads; which were called the *Ten Categories;* viz. Substance, Quantity, Quality, Relation, Action, Passion, Time, Place, Situation, and Habitude. These have been expressed in the following technical distich:

Arbor sex servos ardore refrigerat ustos,
Ruri cras stabo, nec tunicatus ero.

We quote these lines, merely to shew in what way the School-men sometimes exercised their understandings, and what means they devised for the intellectual culture of others.

The Logician's rule for Definition was originally founded upon these Categories; but neglecting its source, it must still be admitted to be perfectly complete and satisfactory.

If the object to be defined, be denoted by a *general* term, join to the name of the *proximate genus* the *specific difference:* thus a *Quadruped* is an *Animal* with *four feet;* a *Square* is a *Rectangle* having *all its sides equal*, or an *Equi-*

lateral Rectangle. In like manner a *Rectangle* is a *Parallelogram* having *all its angles right angles.* A *Parallelogram* is a *Quadrilateral* figure having its *opposite sides parallel.*

And following the same system, if the term be a *particular* one, we are directed, in defining it, to join to the name of the species *specialissima* the *numerical* difference. But definitions of individuals are more properly called *Descriptions.*

Divested of the logical phraseology, and extending a little the application of the term *Definition*, we may represent it to be a statement of those parts or properties of a thing, or circumstances respecting it, which distinguish it from all others. In some cases we can only define by a negation of properties; for instance, the terms, *infinite*, *cold*, &c. admit of no positive definition. Other terms are explicable only by the use of synonymous expressions, or by referring to the things denoted by them: but these are best termed *Explanations.*

A good definition must be applicable to all the particular species or individuals included under the term defined, and at the same time exclusive of all other species or individuals. A definition of *Man* which should exclude the *Hottentot*, and another which should include the *Oran Otan*, would, in a *logical* point of view, be equally exceptionable.—In proportion to the species and varieties included under the generic term defined, must, of course, be the diminution of its comprehension; and it becomes extremely difficult, in many cases, to obtain such a selection of properties, as shall include every individual which ought to be included, and yet be sufficiently exclusive. Plato's definition of *Man*, (viz. *a featherless biped*,) was justly made by Diogenes the object of ridicule; yet we do not learn that the Cynic gave any better.

A definition ought to be itself clear and plain. The terms employed should be precise and intelligible; and they should bring the import forcibly and distinctly before the view of the mind, so that good sense alone should be requisite to make it properly understood. If the terms employed in a definition

are not in common use, they should themselves be first clearly defined: but, in general, if definitions are designed for those who are beginning any science, it is better to err on the side of diffuseness, than to employ terms which are not familiar. Thus for a learner it is surely best that the *square* should be defined, a *four-sided figure having all its sides equal, and all its angles right angles:* yet the same thing, as already mentioned, may be denoted by two words. Though, however, that degree of brevity should be carefully avoided in a definition, which may make its import obscure, no unnecessary terms should be used; and the sole object should be, to give a distinct, clear, and forcible representation or discrimination of the thing signified.

We shall close this chapter with a few connected maxims.

(1.) Do not allow in yourself the employment of words which have, as commonly employed, no meaning at all, or a very loose and indeterminate one, or even one absolutely false. Many persons write and speak nonsense, from inattention to this simple principle.

(2.) In all your private investigations, and in the communication of your ideas to others, accustom yourself to employ words in a precise and determinate sense. Careful attention to the import of words, is necessary to success in the search after knowledge, even when the internal operations of the mind are alone employed. We cannot carry on any long train of thought, without the internal use of words; and we are liable to the influence of their ambiguities, as well in those mental processes, as when engaged in the communication of our ideas. In this last employment, it should be our object carefully to avoid all needless ambiguity; and without entering too much into formal statements of our meaning, it will usually be easy to limit the acceptation of those leading words, on which the correctness and intelligibility of the whole reasoning may depend.

(3.) When engaged on the productions of others, aim to ascertain in what way precisely the author employs his terms,

especially those which are of a somewhat ambiguous nature, and on which the stress of his argument may rest. If it were the object of the reader to ascertain the real meaning of the author, rather than to try his words by his own ideas, which may be incorrect, numberless volumes of wrangling controversy, in every department of knowledge, would never have been written.

(4.) Where distinctions have been laid down by writers of good authority in the use of words, before considered as synonymous, aim to observe the distinction, and to extend its use.* We may sometimes lose in rhetorical effect by such niceties; and undoubtedly they may be carried to an extreme: but it is only by affixing distinct and definite ideas to terms, that we can reasonably hope to carry out of the sphere of mathematics and physics, that precision and certainty which distinguish those sciences.

* *Genuineness* and *Authenticity* were formerly confounded by writers of eminence. The late venerable and enlightened Bishop of Llandaff probably first introduced the distinction now universally adopted; making genuineness refer to the author, authenticity to his statements. A book is *genuine*, if written by the person to whom it is ascribed; *authentic*, if the facts contained in it are true.

CHAP. XXII.

PROPOSITIONS—EVIDENCE—SYLLOGISMS—OBSERVATIONS ON THE PURSUIT OF TRUTH.

PROPOSITIONS:—Subject—Predicate—Copula—Various kinds of Propositions. EVIDENCE:—Certainty—Sense—Consciousness—Intuition—Experience—Reasoning—Testimony—Divine Authority. SYLLOGISMS:—Utility of the Syllogism—Moods—Figures—Complex Syllogisms—Epichirema—Dilemma—Sorites—Enthymeme—Indirect Arguments—Sophisms. PURSUIT OF TRUTH:—Analysis—Synthesis—Generalization—Induction—Analogy—Causes of Error—Qualifications for ascertaining Truth. ADVICE TO THE STUDENT.

A *PROPOSITION* is an assemblage of words, in which one thing is affirmed or denied of another: for instance, *Gold is heavy, Some men are not wicked.* The term is extended, in the mathematical sciences, to include not only the statement of a truth which it is proposed to demonstrate, but also that of some construction which it is proposed to make: in the former case the proposition is called a *Theorem,* in the latter a *Problem.*

Respecting the mental operations which accompany the statement of a proposition, in the mind of the speaker, and of the hearer, we have had occasion to make a few observations in p. 308-311; and we beg to refer the reader to them before he proceeds.

However complex a sentence may appear, yet if there be but one affirmation or negation throughout, it is only one proposition.

That concerning which any thing is affirmed or denied, is the *Subject* of the proposition. The *Predicate* is that which is affirmed or denied of the subject. And the word by which the assertion is completed, is called the *Copula*. Thus in the proposition *Gold is yellow*, *gold* is the *subject*, *yellow* the *predicate*, and *is* the *copula*. The word expressing the negation, is considered as a part of the copula; as in the proposition *Man is not immortal*, *is not* is the copula. Some would also make the negative word a part of the copula, even where it is connected with the subject: thus in the proposition, *No man is without sin*, they make *man* alone the subject. But it is much more simple and natural to regard the negative word as a part of the copula, or of the subject, or even of the predicate, according to its connexion in sense; and it causes no perplexity in logical distinctions to follow this arrangement.

It is not necessary that there should be three separate words to form a proposition. The *asserting word*, or *verb* (see vol. I. p. 66.) may include, in its peculiar form, the subject and the predicate; and there is no verb, except *be* and the corresponding words in other languages which does not include a part of the predicate. Thus *amo* includes *I* the subject, *am* the copula, and *loving* the predicate: in our own language, the subject is never included in the verb, (though sometimes it is left to be supplied from the preceding sentence,) but the predicate is continually included; thus *Troy was*, means *Troy was once existing*. The interesting inference, is merely inference.

When the subject and predicate express precisely the same idea, the proposition is called *identical*. The terms may be the same, and yet the ideas different: as, *Home is home:* meaning that the place where we usually reside, possesses those comforts and delights which give it an exclusive right to the appellation *home*.

Identical propositions are often extremely nugatory; especially those which, though not designed to be explanatory, have their subject and predicate exactly of the same import, and yet are supposed to give information.

Some valuable writers on the nature of mathematical evidence, have caused much perplexity, and obscured truth, by using the term *identical* instead of *equivalent*. To say that the proposition, *The three angles of a triangle are equal to two right angles*, is an *identical* proposition, is an unhappy misapplication of the term. The three angles are *equal* to two right angles; but they are not themselves two right angles.—If a triangle and parallelogram stand upon the same base, and between the same parallels, the triangle is equal to half the parallelogram; but the triangle is not identically the same, though equal in extension with half the parallelogram. The two magnitudes are *equivalent*, not identical; and the proposition itself should not be termed identical.

When the predicate is *affirmed* of the subject, the proposition is *affirmative*; when it is *denied* of the subject, the proposition is *negative*. *Man is mortal* is an affirmative; *All men are not wise*, is a negative proposition. Those propositions in which the negative term properly belongs to the subject, are most conveniently classed with negative propositions, and are universally so regarded by logicians, though in strictness they are affirmative. Thus, *No good man is dishonest*, is considered as a negative proposition.

When the subject of a proposition is a general term taken in its whole extent, (that is so as to extend to every individual included under it,) the proposition is called *universal*. When the subject is limited to some one or more of the species or individuals included in it, it is called a *particular* proposition. *No man is almighty*, *Every creature had a beginning*, are examples of universal propositions: *Few men are truly good*, *There are few men that are strictly upright*, are particular propositions.

When the subject is an individual, the proposition is

termed *singular;* and since the subject is necessarily taken in its whole extent, it is classed with *universal* propositions. The same may be stated of those propositions which though they are *indefinite* from having no mark of universality prefixed, are still in reality universal in their import; as in the propositions, *Drunkards are irrational, A planet is continually in motion,* clearly implying *All drunkards, Every planet.*—There is another class which are arranged under the general head of universal propositions, since the subject, however expressed, is used in its whole extent: namely, those in which the subject is a collection of individuals, not taken distributively but collectively. The distinction is a simple and obvious one. If we say, *Every soldier in the army of Alexander was brave,* we have a *distributive* proposition, and of course the predicate refers to each soldier taken separately. But if we say, *All the soldiers of Alexander made but a little army,* we have a *collective* proposition, where the *all* refers only to the collection of soldiers, not to the soldiers individually.

Universal propositions are often employed with great deviation from logical correctness: and in all compositions, in which the communication of truth is the object, they should be used with caution. Nevertheless, in numberless instances, where not altogether correct, they can produce no difficulty, provided they are interpreted by the plain dictates of common sense; and may be safely left to it for interpretation. The eastern writers, and orators and poets of all ages, abound in these hyperbolical statements: and they must always be received under those limitations and exceptions which the subject naturally imposes.

Before, therefore, we proceed to make deductions from any proposition, we must first of all consider what is its real import, what the speaker or writer meant it to convey. And indeed this simple principle, and one or two others of a similar nature, would of themselves render unnecessary a

multitude of the rules which have been invented by the mere technical Logician, without his at last accomplishing his object, viz. to enable us to perform correctly all the operations of reasoning *secundum artem*, without the aid of the intellect. The rules of sound Logic can have in view only to aid the understanding in its operations, not to supersede them.

Universal and particular propositions are said to differ in *quantity;* affirmative and negative, in *quality*. And to denote the quantity and quality of propositions, with a view to the rules of the syllogism, the first four vowels are employed: A denoting universal affirmative; E, universal negative; I, particular affirmative; O, particular negative. The distinction will be easily recollected, if the learner bear in mind that A and E are universal, and A and I affirmative.

If two propositions differ both in quantity and quality, as (A) *All men are wise*, (O) *Some are not wise*, they are called *contradictory*. One must be true, the other false. If two universals differ in quality, as (A) *All men are wise*, (E) *No men are wise*, they are called *contrary*. Both may be false, but both cannot be true.

When the subject and predicate of a proposition can change places without affecting its truth, the proposition is said to be *reciprocal;* and the change is called the *conversion* of the proposition. This may be made whenever the predicate and subject have exactly the same extension, or the same comprehension: but though in such a case the new proposition may be strictly true, it may not convey the full import of the original proposition in the case in which it was used.

When a proposition simply expresses the connexion between the predicate and the subject, it is called *pure* or *absolute;* when it expresses the way or manner in which the predicate is connected with the subject, it is called *modal*. Thus *A good man must be honest*, is a *modal* proposition. It may be changed into an absolute proposition by making some term equivalent with that which expresses the mode, the predicate, and the rest the subject; thus the foregoing may be

thus changed, *That a good man should be honest is a necessary thing.*

When the assertion is made under certain suppositions or conditions, the proposition is called *conditional* or *hypothetical;* as, *If men follow the laws of duty, they will be happy.*

If the proposition has but one subject, and one predicate, it is termed a *simple* proposition: if it have two or more subjects or predicates, or both, it is a *compound* proposition; as, *Learning and virtue are better than riches and power.*—A compound proposition may be resolved into several simple propositions.

Evidence.

Moral Truth consists in the agreement between our words and our thoughts; when we say what we believe to be true. *Logical truth,* or truth abstractedly considered, is the agreement of words or ideas with reality.

The grounds upon which we believe a proposition to be true, are called *Evidence.* Of evidence there are various degrees and different kinds; and it is one of the most important qualities of a sound understanding, to be able to estimate evidence according to its nature, to perceive its force, and to admit its appropriate influence on the mind.

Certainty expresses the strongest degree of conviction; it also denotes the highest degree of evidence. Certainty considered as a degree of belief, may be formed where there is not the highest degree of evidence; and some minds can resist the highest degree of evidence, so as not to derive certainty from it.

The human mind is so formed, that truths of grand practical importance, from their innumerable connexions with other truths affecting the conduct and happiness of man, and with the frame of nature, and the course of providence, may acquire a degree of conviction, which could not be surpassed by the clearest and most satisfactory evidence of that description which the human mind in a sound state cannot resist.

The religious man feels as strong a conviction in the being and moral government of God, as the mathematician does in a proposition whose demonstration is complete, and which he fully understands. The evidence in the two cases is of a different nature; but the variety, extent, and constantly operating influence of the one, where the mind is properly disposed to receive it, fully compensates for the direct and incontrovertible power of the other. This is an important fact, arising from the constitution of the human mind; and it is intimately connected with the condition of man as an accountable and moral being.—It is one grand object of education so to train up the affections and the understanding, that truth may be loved, and may be readily discerned; in other words, that evidence may have its just and appropriate influence.

Evidence is of various kinds. The *Evidence of Sense*, under certain corrections and limitations, is calculated to produce a high degree of conviction. Indeed as far as relates to the *sensations*, simply considered, the evidence is complete: it is only our associations with them that are attended with uncertainty. The senses, if in a sound state, convey precisely the same information in all cases where the external causes of impressions are the same; the accuracy of our perceptions and inferences from them, is all that is attended with difficulty. See p. 256-258.

The *Evidence of Consciousness* is attended with similar, but greater difficulties. Where it is completely ascertained, it is decisive; but those who have not been accustomed to attend to their own mental states, feelings, and operations, often are mistaken in their notions respecting the evidence of consciousness. In innumerable instances, however, and those of the chief practical importance, it is abundantly clear, and is then fitted to produce the highest degree of conviction.

When the truth of a proposition is so obviously and readily discerned, that no person, who understands the terms, can hesitate in admitting it, it is said to be intuitively true. This is the *Evidence of Intuition*. To call a proposition intuitively

true, when only the cultivated understanding can receive it, would be a misapplication of terms; on the other hand, it is trifling to require proof of those which to plain sense are intuitive.—The term intuitively true is obviously indefinite. A proposition may appear so to one and not to another; and to the same person in different states of mind, a position may require proof, or be intuitively evident. But there are, in every branch of knowledge, some truths which, when understood, the sound understanding cannot reject; and those may be laid down as fundamental maxims We may go further, and maintain, that there are some truths, for which no media of proof could be found so clear as they are in themselves, and which the very constitution of the mind leads us to admit. That it is our duty to obey God, is one of these.

Propositions which are intuitively evident, and made the foundation of other truths, are called *Axioms;* but the term is sometimes extended to those fundamental principles upon which a science depends, even if they require proof, or are derived from a very extensive round of experience and observation.

Experience is often a valuable source of evidence for the truth of propositions. It has a particular reference to that practical instruction and skill in judging, which is derived from the events of life. And where the judgment is good, and the observation has been judicious and extensive, the experience of others and your own is a good evidence for truths which lie within its reach. The dictates of experience should not be regarded as destitute of weight, because the grounds of it cannot be shewn, or because those which are produced may appear inadequate. If a man of observation, good sense, and proper opportunities for acquiring experience, gives a decision founded upon it, it is worth more probably than his reasons for that decision. His reasons will only express a part; his experience is the general result.—These remarks particularly and chiefly apply to that experience which respects the maxims of prudence for the conduct of life.

The *Evidence of Reasoning* is that which arises from the operations by which some truths are inferred from others. Those inferences are termed *conclusions*. If the *premises* from which they are derived are established truths, and the conclusions justly drawn, the evidence is complete. When the premises are intuitively true, being of that class called axioms, or derived by obvious and just inference from definitions, or if they have been previously proved, and the conclusion is drawn with intuitive correctness from those premises, the train of reasoning is called a *demonstration*.

Testimony is a most important source of evidence. It is the only means by which we learn the existence of things, persons, or facts, which do not come under the notice of our own observation, and of which we have no direct proof. The rational influence of the evidence afforded by it, depends partly upon the nature of the fact, and partly upon the nature of the testimony. For some facts, a slight degree of evidence is adequate in proof; for others we require what is extremely strong. And the evidence of testimony may be so strong, that the supposition of its falseness would be more incredible than any position, not clearly false or impossible, which it may be adduced to prove. The supposition that Christianity is false, e. g., involves a miraculous interference of divine power, of a nature infinitely less credible than the reality of those miracles on which it rests for its divine authority.

The two essential conditions for the truth of testimony are, (1) That the witnesses be competent, have had adequate abilities and opportunities for obtaining accurate information: and (2) That they have no intention to deceive others. If we can shew that in any case they could not be deceived, and that not only they had no motive to deceive others, but that every motive which could operate, was against their persisting in their testimony, we have every condition which is requisite for a rational assent to it.*

* The subject of evidence, and especially of that of testimony, is of the

Where, by any medium of proof, we can establish the *Divine Authority* of any proposition, or in other words, prove it to be a declaration of revelation, our conviction of its truth must be of the highest possible kind.

Syllogisms and Sophisms.

Whenever one truth is inferred from another, or a reason assigned for what we assert, there is an act of reasoning. Logicians however employ the term *Reasoning*, to denote those processes of the mind by which the agreement or difference between two ideas is ascertained, by the comparison of them with the third; and the series of propositions in which this process is stated, is called a *Syllogism*, thus:

A. Every virtue is deserving of approbation;

A. Prudence is a virtue;

A. Therefore prudence is deserving of approbation.

The syllogism consists then of three propositions: that containing the inference is called the *conclusion;* the other two are the *premises.*

The subject and predicate of the conclusion are called the *extremes;* that with which they are compared, is called the *middle term,* or *argument.* Of the extremes, the predicate, (as being always taken in its full extent or comprehension,) is called the *major,* and the subject the *minor term.* And of the premises, that proposition in which the major is compared with the middle term, is called the *major proposition,* the other the *minor proposition,* or *assumption.* Thus, in the preceding syllogism, *prudence, deserving of approbation,* and *virtue,* are the *three terms* of the syllogism. *Prudence,* and *deserving of approbation,* are the *extremes: prudence,* the *minor; deserving of approbation,* the *major.* *Virtue* is the *middle term.* The first proposition is the *major,* or *the proposition;* the second

greatest importance; but we can do no more than give our readers such hints as may serve them for a basis; and in our conclusion, they will find references to valuable works, from which they may derive almost all the information they may require.

the minor, or *the assumption*. Both are *premises*. The third is the *conclusion*.—This is the order in all regularly constructed syllogisms.

The syllogistic form of reasoning is not without its utility It assists to give order and precision to an argument; to direct the attention of the mind to that position on which the proof depends; and to make the proof more close and intelligible: and by resolving an argument into the syllogistic form, we are sometimes better able to see its truth, or to detect the sources of error. Where the mind is habituated to the rules of the syllogistic system, it is likely to obtain, from the various exercises to which they lead, great skill and readiness in discovering and rectifying, or combating the false reasonings of an opponent, and in inventing modes of argumentation by which just conclusions may be furnished. The syllogistic system of reasoning may be wisely and well employed for such purposes; or it may be used by selfishness and injustice, to baffle the plain understanding, and to lead away the judgment from that which should be the sole object in all reasoning, the ascertainment of truth.

In those sciences, in which, from the power of precise definition, and the nature of the objects defined, truths may be strictly demonstrated, the train of reasoning often leads to the employment of the syllogistic form; and it may sometimes be useful in others. But the nice gradations of thought, and the innumerable departures from strict accuracy of language, which the nature of language itself almost necessarily produces, are, among other causes, sufficient to render it very undesirable that the syllogistic form should be adopted, in the more usual departments of knowledge. Sound argument may be carried on, and full and just satisfaction given to the mind, without the use of it; and it would extremely check and embarrass the operations of intellect, by the necessity of attending to form, when the substance was perfectly clear.

As to the *discovery* of truth, the syllogism can be of no direct service; for the major must necessarily contain the con-

clusion, if both are true. It answers the purpose of setting the mind to work, in order to obtain proper media of proof; but this end must be obtained by every well-conducted process of reasoning.

The advantages to be derived from the syllogistic system, are generally to be obtained, with greater certainty, from the study of mathematics; and at the same time real knowledge will thus be obtained. Nevertheless, the mental culture afforded by the former, where it is not carried to excess, or allowed to rest in words, ought not to be despised.

Without in any way recommending our readers to enter deeply into the study of the laws of syllogism, or to fetter themselves by minute attention to them, we regard them as deserving the examination of those, whose time will allow of such pursuits; and shall mention the sources of information hereafter. But as many, we doubt not, will be fully satisfied with what they will find here, we shall give them a little idea of the *Moods* and *Figures* of syllogism.

The *Figure* of a syllogism respects *the position of the middle term in the premises: Mood,* the *quantity and quality* of *the premises and conclusion.*

The reader will recollect the import of the four letters, A, E, I, O. (See p. 418.) Now all the possible combinations of four things by three, amount to sixty-four. There may therefore be sixty-four Moods, that is, sixty-four combinations of propositions, in which there shall be some variation in the quantity or quality of the three propositions, or in the order of them. But of these combinations, fifty-three are excluded, by certain rules which the logician lays down; and indeed they are obviously excluded by common sense, as the reader will at once perceive, by forming syllogisms with propositions denoted by AAE, IIA, &c.

One of the eleven remaining Moods is superseded by another, reducing the number to ten; and of these, some only are applicable in one Figure, some in another.

There are four Figures. (1.) When the middle term is the

subject of the major, and the predicate of the minor. (2.) When it is the predicate of both. (3.) When it is the subject of both. (4.) When it is the predicate of the major and the subject of the minor.

In the first Figure there are only four admissible combinations of propositions, or Moods, viz. those denoted by AAA, EAE, AII, EIO: and to denote them, words are selected containing those vowels, and arranged in the following line:

Barbara, Celarent, Darii, Ferio quoque primæ.

There are similar lines for the other Figures;* but as the fourth is useless, being little better than an awkward transposition of the first, and as the second and third may be converted into the first Figure, this alone is regarded as of much consequence. Besides, as will be seen from the last vowels of the Moods, this Figure admits of conclusions of every variation in quantity and quality; whereas the second admits only of negative, and the third only of particular conclusions.

The syllogism in p. 423. is in the Mood *Barbara,* every proposition being a universal affirmative: the following is in *Ferio.*

E. Nothing which is forbidden by wisdom, can be truly desirable.

I. Some pleasures are forbidden by wisdom.

O. Therefore there are some pleasures which are not truly desirable.

The reader will not find it a useless exercise to form syllogisms in the different Figures, but in this he will require no further direction.

Simple or *Categorical* syllogisms are those which are made up of three plain simple or categorical propositions, in which the middle term is evidently and completely connected with

* *Cesare, Camestres, Festino, Baroco,* secundæ.
Tertia *Darapti* sibi vindicat, atque *Felapton*
Adjungens *Disamis, Datisi, Bocardo, Ferison.*

each extreme: but there are various other forms of syllogistic reasoning, of which the following should be noticed.

When the middle term is not completely and distinctly joined with each extreme, the syllogism is called *complex*. The student will probably find various instances among the syllogisms which he constructs by way of exercise; for though complex syllogisms are awkward to bring under the syllogistic rules, they are often perfectly plain and forcible in their conclusion. He may even find it difficult to perceive any thing wrong in the following complex syllogism: The Sun is a senseless being; the Persians worshipped the Sun; therefore the Persians worshipped a senseless being. To make this syllogism *regular*, however, the minor and conclusion must stand thus; What the Persians worshipped is the sun; therefore what the Persians worshipped is a senseless being.

Epichirema is a compound syllogism, which contains the *proof* of the major or minor, or both, before it draws the conclusion.

A *Dilemma* is an argument which, presuming that one of two suppositions must be true, proves that one of them is false, and concludes that the other therefore must be true. If it do not include all the suppositions which may be true, the conclusion is unsound.—If three suppositions are made, the argument is sometimes called a *Trilemma*.

Sorites is an argument consisting of a series of propositions, in which the predicate of the first becomes the subject of the second, and so on, till, in the conclusion, the subject of the first is joined with the predicate of the last: thus, *All who love wisdom*, will earnestly desire it; All who earnestly desire it, will use the necessary means to attain it; All who use the means of attaining it, will encounter many difficulties; All who encounter difficulties, *must exercise patience, perseverance, and self-denial:* Therefore *all who love wisdom, must exercise patience, perseverance, and self-denial.*

Enthymeme is an argument, in which the conclusion is drawn at once from one of the premises, without any formal

syllogism: as, *All sciences are useful; Therefore the mathematics are useful.* This is the most common, and in general the best form of reasoning: it is obviously included in many of those which are called *causal* propositions; such as, *Some words should not be used,* because *they are offensive to delicacy.*

Some arguments are *direct,* immediately proving the proposition in question: some are *indirect,* proving the conclusion, by proving or disproving some proposition on which it depends. Of indirect arguments there are three cases: *Reductio ad absurdum* proves the conclusion, by demonstrating the absurdity of the contradictory proposition: *Argumentum à fortiori,* by proving a less probable supposition upon which it depends: *Argumentum ex concesso,* by proving a proposition on which it was agreed to rest the original question— Various other arguments have been distinguished by Latin names; but these readily suggest the distinctions; and it is unnecessary to notice more than the *Argumentum ad hominem,* which is founded on the opponent's professed principles, whether true or false.

When an argument in the syllogistic form, offends against the rules of syllogism, it is termed a *Paralogism;* when an argument, however arranged, carries the appearance of truth with it, and yet is erroneous, it is termed a *Sophism.*

Of Sophisms various kinds are enumerated by Logicians: the principal are the following. *Ignoratio Elenchi,* or a *Mistake of the Question;* when something is proved which has no necessary connexion or inconsistency with the point really under discussion; and consequently affords no real ground for determination respecting it. *Petitio Principii,* or *Begging the Question;* where the very thing to be proved, is taken for granted. *Arguing in a Circle,* when the premises are proved by the conclusion, and the conclusion by the premises. *Non causa pro causa,* the *Assignation of a false cause;* as when Christianity is charged with being the cause of persecution. There are few more extensive sources of error, than the mis-

take between the *post hoc* and the *propter hoc*. *Fallacia Accidentis*; arguing from what is accidental to what is essential. *A dicto secundum quid, ad dictum simpliciter*; when we argue from that which is true in particular circumstances, to prove that the same thing is true absolutely, and in all circumstances. *Sophisms of Equivocation*; when the argument depends upon the ambiguity of the terms.

The grand principles by which we are to try every argument, whether directly syllogistic or otherwise, are, that the terms employed in it, be used in precisely the same sense throughout; that the premises be themselves just; and that they afford a full justification of the conclusion. And in applying these, sound sense and the habit of discrimination are our best guides.

Observations respecting the Pursuit of Truth.

There are two leading methods of investigating truth. In one case we begin with the various phenomena, or objects of thought, as they are; and gradually proceed to first principles, or elementary truths: this is the *Analytical Method*.—In the other we begin with simple principles, and gradually advance to the more complex forms of the subject under consideration: this is the *Synthetic Method*.—It may illustrate this, if we suppose a person, when communicating chemical knowledge, to begin with some compound substance, (*water* for instance,) and shew into what elementary substances it may be analyzed, or separated: he is there pursuing the method of Analysis. If he then proceed to shew the various combinations of those elementary substances, and explain the laws and properties of each, he is adopting that of Synthesis.*

In geometry these terms are employed with some diversity of acceptation. If the proposition to be demonstrated is supposed to be true, and consequences are deduced from it, and

* Reasoning *à priori* is arguing from first principles, or from causes to effects; reasoning *à posteriori* is from the effect to the cause: the latter corresponds with *analysis*; the former with *synthesis*.

others from these, till at last we reach a position which can be ascertained to be true or false by comparison with one which is known to be true, the truth or falsehood of the original proposition is said to be established by *analysis*:* if it be done by a series of direct inferences from established truths, then the method is called *synthesis*.

The analytical method of *investigation* is that which is now pursued in every department of science: and the success of it depends upon a comprehensive and accurate induction of particulars.

The object of philosophy is to observe and examine phenomena, and from the examination of them under various circumstances, to derive those general laws or principles, *agreeably to which* they take place: and next to apply these laws to the explanation of other phenomena. The former process is *Generalization*. If it be founded on an accurate examination of a sufficient number of particulars, under a sufficient variety of circumstances,—in other words, on a correct and adequate *Induction*,—and the conclusion is borne out by its consistency with all known phenomena, and by its affording a satisfactory explanation of such as correspond to those from which it was derived, this conclusion is to be regarded as an established principle, or general law.—In the investigation of less extensive principles, the same process is pursued; though of course with less difficulty, and greater probability of success: and with the necessary variations arising from difference in the nature of the particulars, the same method is to be pursued wherever general conclusions are to be derived from particular facts.

There are numerous cases, however, in which experiment and induction cannot be employed. Here analogical reasoning is often advantageous. By *Analogy*, the similarity of

* It is apparently on the same principle, that algebraic investigations are called analytical. *Data* are laid down as true, and the *quæsita* deduced from them.

causes or general principles is inferred from the resemblance or correspondence of circumstances. Important truths have often been obtained by this means; and conjectures founded on a good analogy, have afterwards been established by direct proof. It is found peculiarly applicable to the obviation of objections against truths already ascertained. Bishop Butler, in his Analogy, has employed it, with complete success, for the vindication of religion, natural and revealed, by shewing that the objections urged against it, lie with equal force against the course of nature; and, therefore, if we admit that the latter has God for its author, these objections have no weight against the former.

In the pursuit of scientific truth, the two great errors are, on the one hand, resting with a crude mass of facts, or phenomena, without classification, discrimination, or generalization; and, on the other, generalizing too soon and too rapidly. If the mind is in the sluggish state, which the former supposes, it will not be likely to observe phenomena so as to discern the essential characteristics or circumstances of them; and the application of the facts observed, will often be founded on those circumstances or qualities which are in reality of no moment. If we generalize too rapidly, our inferences from our general principles will often be alike fallacious, though from a different cause.—Similar remarks may, in both cases, be made, respecting *experience*, connected with the conduct of life.

The following are stated by Mr. Stewart, (Elements, vol. II. p. 274.), as among the most powerful causes of erroneous conclusions in scientific researches. "(1.) The imperfection of language, both as an instrument of thought, and as a medium of philosophical communication. (2.) The difficulty, in many of our most important inquiries, of ascertaining the facts on which our reasonings are to proceed. (3.) The partial and narrow views, which, for want of information, or from some defect in our intellectual comprehension, we are apt to take of subjects, which are peculiarly complicated in

their details, or which are connected, by numerous relations, with other questions equally problematical. (4.) And lastly, (what is of all, perhaps, the most copious source of speculative error) the prejudices which authority and fashion, fortified by early impressions and associations, create to warp our opinions." All these causes operate also in the pursuit of moral and religious truth; and to them must be added, (5.) The influence of that numerous and extensive class of prejudices, which arise from the dispositions and affections, particularly where our selfish principles, in their various ramifications, are directly, or indirectly concerned.

Pre-supposing a sincere love of truth, good sense, the habit of correct observation, and a discriminating judgment, the qualities and circumstances most necessary for the successful pursuit of important truth, appear to be the following. (1.) Accurate attention to the import of words. (2.) Careful consideration of *all* the circumstances on which a decision is to be founded. (3.) A cautious selection of those points on which the proof really rests. (4.) The rejection of all considerations which have nothing to do with the question. (5.) Activity and perseverance in the investigations required by the object. (6.) Coolness and patience, to prevent precipitancy in drawing conclusions. (7.) Independence of mind, in opposition to authority; and fortitude, in opposition to inconvenience or injury resulting from truth. (8.) Humility, in estimating our own powers and success. (9.) Candour, in allowing just weight to the arguments of opponents, and in discerning truth in the midst of error. (10.) A disposition to be decided by the weight, not by the number of arguments or evidence. (11.) To reject no principle merely because it is new, or inconsistent with our former opinions; yet (12.) To reject no opinion because it has been generally adopted. (13.) To adhere to first principles, where really sanctioned by judicious and extensive experience, by the laws of the mind, and by the course of providence.

In short, a sincere and ardent love of truth, firmness, acti-

vity, and caution in the pursuit of it, and a clear, manly, independent, discriminating understanding, can scarcely fail, when under the control of sound and comprehensive moral principle, to lead to such enlarging and beneficial results, as will amply repay all the exertions and self-denial, by which they have been attained.

Advice to the Student.

If the nature of this work, and other circumstances, had permitted, it would have afforded us great pleasure to assist in supplying a deficiency which must have been felt by many,—that of a brief but comprehensive treatise on the conduct of the understanding, in which the various important directions which have been given by different writers since the time of Locke, should be brought into one point of view, and their influence shewn on the pursuitof knowledge and theconduct of life. The few hints already given, may be of service to the intelligent reader; and from the following course of study he may derive extensive and valuable information, from which he may, for himself, form a practical summary of the kind alluded to. Indeed, we strongly recommend him to reduce to a simple didactic form, and properly to arrange, all the maxims he may meet with in the writings of others, or which his own experience may suggest.* The exercise itself will be of great advantage; and in the pursuit of knowledge he will find, that where those maxims are well founded, they will preserve him from many errors, and accelerate his progress.

If he wish to make himself master of the syllogistic system of reasoning, he may be referred to the Port Royal Logic, and to that entitled Art of Thinking. In Watts's Logic, however, he will probably find enough to satisfy his mind; especially if he add the information which he may derive from

* The *Aphorisms* of judicious and intelligent men, are often of great value. Among the many excellent maxims of *Whichcote*, some will be found bearing on our present subject.

Belsham's Elements.* In a less technical form he may see the essential principles of syllogistic reasoning in Kirwan's Logic, vol. ii.; and many useful hints may be derived from Collard's Essentials of Logic. This last work, however, has not the merit of clear and distinct arrangement; and though it contains, with great diffuseness, what the author regards as the essential principles of the syllogism, yet it does not at all enter into the much more important departments of Logic which respect evidence, words, and the proper conduct of the understanding.

A work of very superior merit is Duncan's Elements of Logic: but it is diffuse; and as far as mental philosophy is concerned, it is sometimes erroneous, and often far from precise. Still it well deserves the perusal of the student.

As to the real value of the syllogistic system, he should consult Kirwan, who defends it against Locke. Our great philosopher was probably led to carry his objections too far, from the use then made of that branch of Logic; and Mr. Stewart appears to have fallen somewhat into the same error, though from a different cause; but his appreciation of it is, on the whole, as just, as his examination of it is interesting. In addition to these works, the student should peruse Dr. Reid's account of Aristotle's Logic, in Lord Kaimes's Sketches, vol. iii.; and he will then have gone through a pretty complete course respecting the syllogistic system.

On the subject of Moral Evidence, we recommend to the reader a little volume of great value, entitled Gambier's Introduction to the study of moral evidence. In Kirwan's Logic he will find many just and important observations, relative to the evidence of testimony.

On the general direction of the understanding in the pursuit of truth, the student will find his account in a close perusal of Locke's Conduct of the Understanding; and in Watts's Logic, and his Essay on the Improvement of the Mind, he

* To this work, and more particularly to Watts's Logic, we have in various parts been indebted.

will see numerous practical hints of great value. Of the former treatise, Part II. ch. iii., on Prejudices, and Part III. ch. iii. on Sophisms, are particularly valuable. After reading these works, and the parts of Mr. Locke's Essay which bear directly on the subject, he will proceed with advantage, to the important and elegant investigations of Mr. Stewart, in the second volume of his Elements.

To those who have not time or inclination to follow this course, we would recommend a thoughtful perusal of Locke on the Conduct of the Understanding, Watts's Logic, (especially the parts above specified,) and Gambier's Moral Evidence, as forming together a very useful and generally valuable directory of the understanding.

The study of authors who reason closely, and with force and precision, may be regarded as a practical means of learning Logic. The geometrical branches of the mathematics are of great benefit in this respect; but the perusal of them should be accompanied with the study of moral evidence.

To those who may rate too highly the advantage of argumentative skill, we recommend the following observations of Mr. Stewart (p. 283.) with which we will conclude. "I have long been accustomed to consider that promptness of reply and dogmatism of decision, which mark the eager and practised disputant, as almost infallible symptoms of a limited capacity; a capacity deficient in what Locke has called (in very significant, though somewhat homely terms) *large, sound, round-about sense.* In all the higher endowments of the understanding, this intellectual quality (to which nature as well as education must liberally contribute,) may be justly regarded as an essential ingredient. It is this which, when cultivated by study, and directed to great objects or pursuit, produces an unprejudiced, comprehensive, and efficient mind."

CHAP. XXIII.

POLITICAL ECONOMY.

History of Political Economy:—Objects of—Writers in, how classed. Nature and effects of Wealth—Definitions of Wealth—The passion for wealth is universal—Various systems concerning the sources of wealth.

POLITICAL ECONOMY is a science peculiarly entitled to the attention of persons possessing the advantages of a liberal education, being that which relates chiefly to the production, augmentation, and distribution of the finances of a state. The acquisition of wealth has at all times been an object of interest to mankind. Yet it was not for a long time reduced to a political science, but was left to the exertions and practical observation of men engaged in the different branches of industry. Among the ancient writers there is scarcely any thing to be found that even bears upon the subject of the "Wealth of Nations." Among them, Agriculture was much more respected and attended to than either trade or manufactures, the latter being, indeed, almost entirely abandoned to slaves. During the middle ages, the feudal system was hostile to a regular system of improvement in agriculture, and absolutely precluded any important progress in manufactures and commerce. These took refuge in the large and flourishing towns, whose fortifications could secure the inhabitants from lawless

inroads, and where a regular police could, in a good measure, secure the persons and property of individuals. The gradual growth of these towns led to the civilization of modern Europe. Articles of beautiful workmanship which were produced, and the various means which ingenuity discovered for multiplying the accommodations of life, in time, brought about a complete change in the habits of the landed proprietors. Till now, power, not wealth, had been their chief object; and to promote this, they spent almost all their revenues in maintaining a crowd of idle retainers. But when, by improvement in the arts they had acquired a taste for luxury, the gratification of which required an augmentation of wealth, their object came to be, how they could turn their estates to the most advantage, which led to a better system of agriculture. The same tastes drew them to large towns; this led to extravagant habits, which frequently brought their estates to market, and placed them in the hands of those who were engaged in commerce and manufactures. Hence it has been inferred, that the improvement of modern Europe began with the manufacturing and commercial classes, and was by them carried to the agricultural part of the community. It was on this account that commerce and manufactures were long looked upon as the grand source of wealth, and the objects claiming the peculiar favour of the legislature. From this circumstance arose the mercantile system, which was so long predominant in Europe; and which has been ably illustrated in the writings of many of our conntrymen, such as Davenant, Petty, and Child.

This system had a powerful influence on the legislation of different countries. In France, more than in any other nation, it reigned with absolute sway. Colbert, the prime minister under Lewis XIV. in his zeal for the promotion of trade and manufactures, not only neglected, but even depressed agriculture, by laying restraints on the exportation of corn. This led many thinking men to attend to the consequences to which such a system seemed to tend; and in their view, agriculture

was the only source of wealth. This opinion was first publicly avowed by M. Quesnai, a physician in Paris, who was looked up to as a leader of a new theory, by many, who espoused his doctrine with all the enthusiasm of devotees to a sect. They assumed the name of "Economists." M. Turgot, in the reign of Lewis XVI., in the reforms which he undertook during his short administration, was chiefly guided by the principles of the Economists.

Dr. Adam Smith, about the middle of the last century, as one of the professors at the University of Glasgow, began to illustrate and explain the principles of political economy. After a few years he travelled into France, and became intimately acquainted with the leading members of the Economical school. On his return, he spent nine or ten years in preparing his great work, entitled "An Inquiry into the Nature and Causes of the Wealth of Nations," in which he has shewn the errors of the mercantile system; and pointed out in a masterly manner many defects of the opposite, or economical theory. This great work was first published in 1776, and for many years it was referred to by politicians and statesmen of the highest rank, as containing the most salutary and undeniable principles, which, if adopted in practice, would infallibly lead to public and national prosperity.

According to Dr. Smith, by whom we shall be chiefly guided in this and the following chapters, Political Economy is the science in which the Wealth of Nations is considered. Its object is to ascertain, in the first place, in what wealth consists, and then to explain the causes of its production, its increase and diminution, and the principles on which it is distributed through the different orders of society. It likewise, in practice, endeavours to point out the tendency which any political regulations may have to augment or diminish wealth.

The writers on political economy, as we have seen, have been usually arranged in two great classes: the former composed of those who regard *commerce*, and the latter of those who consider *agriculture* as the principal source of national

wealth. The commercial system of political economy is very ably explained and illustrated by Dr. Smith in the "Wealth of Nations."

A striking and very important difference between the systems of political economy, as detailed a century ago, and that introduced by Adam Smith, consists in this: that the former are calling, upon all occasions, for the regulation and control of laws; regarding the legislature as best qualified to estimate the value of any particular branches of trade, or modes of conducting business; while by the latter the merchant is supposed to be the best judge of the most eligible method of conducting his own affairs. The former has been rightly denominated a system of restrictions and encouragements, in which little is left to the choice and sagacity of individuals: in the latter it is supposed that national wealth, which is the aggregate of individual wealth, will increase most rapidly, where, while private property is rendered sacred by the laws, talent and enterprise are under the least possible restraint. Having spoken thus generally on the subject, we shall advance to particular details, beginning with an inquiry into

The Nature and Effects of Wealth.—Whatever be the nature of wealth, it cannot be denied, that it is the object of the ambition of individuals and nations, the cause of their quarrels and contentions, and not unfrequently the reward of violence, of fraud, and injustice.

Some writers, as Sir William Petty, state the wealth of a nation to consist in the totality of the private property of its individuals; others in the abundance of its commodities. Some, distinguishing *public* from *private* wealth, assign to the *former* a value in use, but no value in exchange; and to the *latter* an exchangeable value, but no value in use; and these make public wealth to consist in the exchangeable value of the net produce. Others say, that wealth consists of all the material commodities which man may use to supply a want, or to procure an enjoyment either to his sensuality, his fancy,

or his vanity. One defines wealth to be whatever is superfluous. M. Canard, a modern French writer, in his "Principes d'Economie Politique," calls wealth the accumulation of superfluous labour. To common apprehensions, wealth in the simplest and most general acceptation of the term, consists in the surplus of produce above consumption, or of income above expenditure. The extent both of public and private wealth depends, it should seem, on the accumulation of this surplus, and on the manner in which it is managed and applied. When individuals and nations have not enough to supply their wants, they are poor; when their means are exactly adequate to all their wants, they are equally removed from poverty and wealth; and when they have a surplus left, after supplying all their wants, this surplus constitutes wealth.

The passion for wealth is universal, and the history of man and civil society shews that it is always active and enterprising. It is the spring of almost all our actions. It has been the principal promoter of the intellectual faculties, of liberal and mechanical talents, of ingenious and active industry. It has afforded mankind ample means and vast resources; secured them against want, procured them conveniences, comforts and enjoyments the most exquisite; and extended, as it were, the dominion which nature destined for man, so that the distance which separates mankind from the animal creation, might be measured by the distance of the most refined enjoyments from the ordinary wants, or, in other words, by the distance of wealth from poverty.

This passion for wealth, which nature designed for the most useful and beneficial purposes, has also been a constant source of disorder, violence, and calamities, among individuals and nations. Ancient history, and the records of the middle ages, continually exhibit the passion for wealth, as an obstacle to the safety, the liberty, and happiness of individuals: to the independence and prosperity of nations, and to the increase and welfare of mankind. It was ever arming

men against men, cities against cities, and people against people.

Modern nations are not less addicted to the passion of wealth, than the nations of antiquity, and of the middle ages; but they have been more enlightened or more fortunate in the direction which they have given to that passion; and wealth, it has been assumed, has been in these days as productive of public and private prosperity, as it had been before of general and individual distress. Produced by labour, it has rendered men attentive to the means of augmenting the productiveness of labour. They soon perceived that the free labourer who works for profit, multiplies the produce he consumes during labour; while the slave or bondman scarcely replaces what he consumes. Wealth, produced by labour, maintains in nine-tenths of the people, the strength, energy, and dexterity, with which man is endowed by nature; and it developes in the remaining tenth, those faculties of the mind which seem beyond the sphere of humanity, and which bring man, as it were, nearer to the divine nature. Produced by labour, wealth banishes idleness, and the vices unavoidably connected with idleness; it renders man laborious, patient, economical, and at the same time adorns him with those precious qualities, the sources of individual, domestic, and social virtues. It binds the natives of the same land by the most powerful ties, mutual wants and reciprocal services. It has rendered nations more powerful, because every individual member is interested in the success of national affairs; all bear their weight, and all share in the advantages which they procure. This community of good and evil, to which the circulation of wealth calls every individual of the nation, affords the greatest strength which the social compact possibly can or ever did produce. This stimulus is active among industrious and commercial nations, and its strength and intensity can never be impaired or lost. Whatever may be the stock of riches accumulated through

labour, it impoverishes no one; on the contrary, it enriches every individual: it is the instrument of general wealth; it increases the mass of labour, and the sum of its produce; and, consequently, augments the resources of the laborious, and the treasures of the rich. The effects of wealth produced by labour are felt alike by the nations that compose the great family of mankind, and by the individuals who compose each national family. In this system, it is the interest of all to labour, the one for the other, and to increase the stock of general wealth. The labour, industry, and commerce of every individual is useful to all, whatever portion of the globe they may inhabit. The more extensive agriculture of one country is beneficial to all laborious, manufacturing, and trading nations; it increases the produce destined for general consumption, which, in its turn, augments population; and this augmented population affords new consumers of the productions of the industry of every nation. Thus all nations share in the prosperity of each, and the portion of each is proportioned to its labours, manufactures, and commerce.

Of the various Systems concerning the Sources of Wealth.—The most ancient system concerning the sources of wealth, derives wealth from foreign commerce; that is, from that commerce in which one nation sells more to other nations than it purchases, and is paid for the surplus of its sales over its purchases in precious metals. Almost all consider commerce as the true way to grow rich, and by commerce they understand the exchange of commodities with foreign nations. In proof of which, it is said, with reference to Phœnicia, Alexandria, Carthage, Rome, &c., that if we ascend ever so high in history, we find that wealth always followed the direction of foreign commerce, and remained faithful to its banners and ships. The question is, How does commerce enrich a country? By what channels does it pour its benefits? And how is the productiveness of commerce to be increased, and its prosperity insured? Most writers suppose that foreign commerce enriches a country by the

plenty of gold and silver which it causes to circulate, and hence governments endeavour to retain the precious metals; or to invite them, either by encouraging national manufactures, or by directly or indirectly prohibiting the produce of foreign industry, or by procuring to the produce of national industry an easy and even privileged introduction into foreign countries. Such is the system which places the source of wealth in foreign commerce, and which, on that account, has been called the mercantile system.

The mercantile system was very general till M. Quesnai acquired great celebrity by the new views of his "Theory of the Sources of Wealth." He does not place the source of wealth in commerce, because all its operations are limited to the conveyance of the produce of the soil and of industry from one place to another. Neither can industry aspire to this eminent prerogative; because it only transforms the territorial produce into different shapes, without adding any thing to its quantity; and because its productions are only the material representatives of the produce of the soil, which the manufacturer has employed or consumed. Land alone, according to this system, is the true source of wealth, because it produces every thing that man desires for the supply of his wants, and because it constantly reproduces a quantity superior to what has been consumed to effect its reproduction. This excess of reproduction, this gratuitous gift of the soil, this net produce, is the only fund that can be employed to encourage the progress of labour, to reward its success, to promote improvements, and indefinitely to increase the sum of public and private wealth.

Agricultural labour, by a necessary consequence, is the only productive one; all other labours are barren and unproductive. By another consequence, the surplus of the produce of the soil above all expenses to obtain it, being a gratuitous gift of the land, ought to belong to the land-owners; they alone can distribute it to the other classes of the community, a circumstance that gives them the character of paymasters; and to those who receive it, the character of mer-

cenaries. On this respective paying and being paid, the economists built the relative rights of governors and governed. They asserted, that the land-owners, as paying, ought alone to share in the government; and that all those who are paid, cannot take any part in it without an evident and manifest usurpation; and finally, M. Quesnai maintained, that the net produce being the sole disposable wealth, the public revenue can only be derived from part of this produce; that the act of sharing in the net produce renders government a co-proprietor of the soil; and that this co-proprietorship constitutes its right to government, which right is limited by its co-proprietors.

At this period, the principal writers on political economy, and who defended the mercantile system, were all Italians, who made wealth depend on the unlimited liberty of foreign commerce, and triumphantly refuted the system of the French economists. Dr. Adam Smith then inquired into the nature and causes of the wealth of nations, and combating the mercantile and agricultural system with weapons equally formidable, assumed other principles, and was, as it were, the creator of the science.

Notwithstanding the high rank which Dr. Smith holds, Lord Lauderdale has asserted, in a work which he published a few years back, that he had no fixed opinion as to the *sources* of national wealth, and quotes some passages from his celebrated work in defense of this assertion. In one place Adam Smith says, "that the annual labour of every nation is the fund which originally supplies it with all the necessaries and conveniences of life, which it annually consumes; and which consist always either in the immediate produce of that labour, or in what is purchased with that produce from other nations." In another place, he says, " lands, mines, and fisheries, replace with profit not only the capitals employed on them, but all other capitals employed in the community;" in a different part of his work, it is stated, " that the real wealth of a country consists in the annual produce of its land and labour;" then "that the land and capital stock are the two original sources of

all revenue, both private and public; capital stock pays the wages of productive labour, whether employed in agriculture, manufactures, or commerce;" and lastly, he asserts, that we ought to consider "land, labour, and capital, as being, all three, sources of wealth; for whoever derives his revenue from a fund that is his own, must draw it either from his labour, his stock, or his land." These passages are, no doubt, difficult to reconcile; nevertheless, upon an attentive review of the whole work, it seems certain, that he placed the source of wealth in labour, which fixes and realizes itself in some particular subject, that lasts for some time, at least, after that labour is past, whose power is augmented by subdivision, which is developed by trade, improved by competition, and proportioned to the extent of the market, capital, and wages.

Ever since Dr. Smith published his great work, no other theory has been proposed; and though he may not have assigned the limits of the science, nevertheless he has so well determined its principles, that it will be impossible to miss or go much astray from the doctrine which he means to establish. Lord Lauderdale, who has criticised some fundamental points of Dr. Smith's derives wealth from land, labour, and capital: and he goes farther; he attempts to determine the share which each of these sources has in the formation of public wealth.

Such are the various systems concerning the sources of wealth. Though they appear at variance, their difference is little more than nominal, and of very little importance to the science. The partisans of the mercantile system do not assert, that the precious metals which are accumulated by commerce in a country, are not derived from the produce of land, labour, and capital; they even take it for granted that it is so. Again, the French economists do not pretend to believe, that the soil spontaneously yields wealth; so far from it, that they allow, if land be the source of wealth, it is agriculture that multiplies it; and by agriculture they

understand the labour and capital of the husbandman; they even admit that the exchangeable value of the agricultural produce is the measure of wealth of a nation; and that this exchangeable value can only be obtained by the free concurrence of the home and foreign trade; in this way the economists themselves derive wealth from land, labour, capital, and commerce. By placing the source of wealth in labour, which fixes and realizes itself in some permanent object, Dr. Smith likewise admits the co-operation of land, labour, capital, and commerce. Finally, the system of the earl of Lauderdale differs from the other systems only as far as his lordship assigns a particular importance to capital. In every other respect the noble lord coincides more or less with the agricultural system, and the system of labour.

Thus, it is evident, that it is not properly concerning the sources of wealth that the different systems vary; they all, in fact, acknowledge that wealth is produced by the concurrence of labour, land, capital, and commerce; they chiefly differ respecting the more or less important share which they assign to each of these causes: in this consists their difference, and in this lies all the difficulty of the science. On these subjects we shall in the next chapter speak more fully.

CHAP. XXIV.

POLITICAL ECONOMY,

Continued.

Wealth, from what produced. Revenue derived from land. Principle of the variation of rents. Different kinds of Land. Mines. Fisheries. Revenue derived from labour. Wages, how regulated. Circumstances which cause a rise of wages. Productive and unproductive labour. Various theories concerning labour as a source of Revenue. Which kind of labour most productive. Causes that invigorate labour, improve its powers, and meliorate its produce. Division of labour. Machinery. Of the numbers that do not contribute to produce food. Various systems concerning capital. Different ways in which capital is employed.

ALL wealth is either produced by the spontaneous bounty of nature, or it is the fruit of human industry, or it is generated by the judicious employment of a quantity of wealth previously accumulated. To these three heads, that is, to *land*, *labour*, and *capital*, all national wealth has been referred by Dr. Smith, and many other writers on this subject. The Doctor has, however, in many parts of his work considered and represented labour as the only source of wealth. But labour, and the same may be said of land and capital, is

only a mean of furnishing or increasing a supply of those articles for which there already exists a demand; and unless there be a demand, the most arduous exertions will meet with no remuneration whatever.

Of the revenue derived from land. All land capable of cultivation affords something more than is necessary to pay the expense of working it. This surplus goes as rent to the landlord, who relinquishes to the farmer the produce of cultivation. The proportion of the produce of land, which is to be reserved for rent, varies with different circumstances: of these, the principal are, the fertility of the soil—the extent of the demand or market—the prosperity or poverty of the country, which causes a greater or less demand for that produce; and the skill and activity of the cultivators or farmers. In other words, the rate at which farms let, must, like the price of all other commodities, depend altogether upon the demand and the supply. If farming is reckoned a gainful concern, many will bid for farms, and the rent will be raised by competition, and *vice versa*. Land which produces food for man, whether directly or indirectly, will always afford rent to the landlord, in proportion to its fertility and the circumstances just enumerated. Men multiply in proportion to the means of subsistence, and as has been shewn by the ablest economists, they have a tendency to multiply beyond those means; hence there is at all times a full demand for this species of produce. The rent, therefore, afforded by the land which is employed in cultivating food, regulates the rent of all other species of land. No one, unless he was forced to it by peculiarities of soil, would cultivate an article that afforded less rent than this. While, however, there are soils which are only fit for the production of an inferior article, there are others well adapted to the production of those that are of higher value than that of bread corn. These observations apply to that produce of land which is the result of human labour; for with respect to the spontaneous produce of land, it depends on circumstances whether it does or does

not yield any profit. In a rude state of society, this produce will scarcely bear any value. Uncivilized, and uncultivated countries are often covered with immense woods, the cutting down of which is a burden rather than an advantage, whereas in an improved country the wood would afford a very large revenue. Most of the materials of clothing and lodging are of this nature. In the infancy of society, the great object is food: provided men can procure that, they are satisfied with very moderate accommodations in other respects. The hides and furs of the beasts which they kill in hunting, will supply all their wants with regard to covering. But as society becomes more opulent, and luxury is introduced, clothes are among the favourite objects on which this luxury is vented: an increase, therefore, takes place in the demand for its materials. The same may be said of those of lodging and furniture. *Mines* may be considered in the same light as land: they yield a rent which, however, is generally less than that of land. Coal, a very important article in this country, is kept down in price by its relation to the price of wood, otherwise wood would be preferred as fuel. The rent of a coal mine is from one fifth to one tenth of its produce. The tin mines of Cornwall, the richest in the world, yield in rent only about a sixth part of their gross produce. *Fisheries* form another source of wealth similar to land and mines. The sea, however, has never yet been appropriated, nor a rent exacted for its use. But the right of fishing has, in some seas of peculiar fertility, been claimed as national property. River fisheries frequently produce a high rent.

Of the revenue derived from labour. The great source of exchangeable commodities is the labour of man: even those powers of nature for which rent is paid, rarely afford any thing valuable, unless aided by human efforts. Capital, however powerful an instrument, consists merely of accumulated labour. Originally the fruit of every man's industry would belong entirely to himself, but when once lands came to be appropriated, the proprietor of the land claimed, as his right

from the cultivator, a share of the produce. As the state of society became more complicated, and markets more remote, something more would be requisite. It would be necessary to have subsistence, while the article was in the progress of production, and carrying to market, and to be able to purchase materials on which to work, and to command a fixed capital in order to render labour more productive. For all these purposes, capital would become necessary, and the person who had accumulated a portion of it, would be able to command the services of several others, to whom he would advance subsistence and the materials of working, and would receive in return the fruits of their labour. As capitals accumulate, this becomes almost universally the case; in a commercial state, few independent workmen are to be found.

The price of labour or wages is regulated like every thing else by the demand and the supply. If there are many who want and can employ workmen, and if few of that description can be found, the competition of the masters will raise the wages, until the whole capital, not otherwise employed, is distributed among that small number of workmen. Under different circumstances, workmen, willing to work for almost any thing rather than starve, will bid against each other till they are all employed, at however low a recompence.

The supply of labour, that is, in fact, the population of a country, has a natural tendency to suit itself to the demand. High wages, by encouraging early marriage, and enabling the labourer to take better care of his children, soon cause an addition to the numbers of a state, which in its turn brings down the wages. Hence uncommonly high wages take place chiefly in an advancing state of society, when a number of employments are open, for which a sufficiency of labourers cannot be found. When the wealth of a country is stationary, the wages will be moderate, but sufficient to rear such a number of children, as may keep up the population, but not such as to admit of any increase. When the country is in a de-

clining state, the wages will necessarily fall below this, they will scarcely enable the labourer to subsist, comparatively few will be able to rear families, and the population will decline. It has, therefore, been inferred, that the price of subsistence has not, and ought not to have any immediate influence on the wages of labour. For the demand for labour, the funds by which it is paid, and the number of labourers continuing the same, no alteration in its price will take place. For masters, therefore, to give higher wages on account of scarcity is, probably, an injudicious act of benevolence. The funds for the maintenance of labour, are rather diminished than increased by a dearth, so that the giving a greater proportion of them to some, must be the means of throwing others altogether out of employment, and to this cause may be ascribed the want of work usually complained of at these periods. Where the rise of provisions is permanent, that of labour, though not immediate, must ultimately take place, in consequence of a diminution of the supply.

Wages, in general, are the same, or nearly so, over a whole country; for if they are higher in one place than in another, it becomes a natural attraction to those of other districts, who soon reduce the rate to a proper level. Wages are usually higher in cities than in the country, because the capitals there are greater. The country also is more prolific, while few towns keep up their own numbers. Many, indeed, migrate from the country to towns, but the natural attachment which people feel for their native spot, and to the more wholesome and cheerful occupations, prevents this migration from being so great as entirely to equalize the rate.

Wages, however, vary not only from local causes, but from others connected with the nature of the employments by which they are earned. There have been enumerated five circumstances which tend to raise the wages of any class of men above the ordinary level. 1. When the employment is unwholesome, or even disagreeable. 2. Where a profession

is difficult to learn. 3. Where the employment is precarious. 4. Where great trust is reposed in the workman. 5. Where there is any peculiar risk.

There are besides these, some circumstances, to which all trades are occasionally liable. In a new trade the wages are generally higher—an extraordinary demand likewise raises wages: on the other hand, sometimes work is done cheaper than usual from being taken up as a bye employment by those who derive the main part of their subsistence from a different source. This takes place, however, only where the demand for labour is slender; in other circumstances, the whole of a man's time may be advantageously employed.

In considering the effects of labour in the production of wealth, Dr. Smith divides it into two kinds, which he calls productive and unproductive. By productive labourers he means those whose industry produces a commodity which remains and can be exchanged for another: thus the farmer produces corn, the manufacturer cloth, &c. The unproductive are those whose services perish in the moment of performance, and never produce any commodity to which value can be attached. These include a variety of professions, as well the most respectable, as the least so. It includes all those employed in the executive government, public teachers, menial servants, players, musicians, &c. The more a man maintains of the former kind of labourers, the richer he becomes; the more he maintains of the latter, he becomes the poorer.

Having given an outline of Dr. Smith's theory respecting labour, we shall consider some other theories concerning labour as a source of wealth. In every system of political economy, labour has the greatest share in the formation, increase, and preservation of wealth. If the labourer find the precious seeds of wealth in the spontaneous gifts of the soil, he fertilizes, multiplies, varies them by his activity, his skill, and his industry; and obtains results so new, so different, and so remote from their nature, that he may almost be regarded as the creator, rather than as the co-operator in obtaining

wealth, and hence Canard defines wealth to be "an accumulation of superfluous labour."

On this subject many interesting questions occur: Is this productiveness of labour exclusively reserved to one, peculiar to a few, or common to all sorts of labour? Is there, among the different kinds of labour, any one more especially productive, and favourable to the progress of wealth? Is agriculture more conducive to wealth than manufactures and commerce? What are the means of rendering these different labours more productive and more profitable? Which are the obstacles that oppose their progress, and impede their success? These questions it will be interesting to investigate as far as the nature of our work will allow.

The economists assign, exclusively, to agricultural labour, the power of producing wealth, and regard every other kind as barren and unproductive. They do not deny the usefulness of what they call unproductive labour,—they only *limit* its utility; and assert, that with regard to manufactures, this utility consists in the adaptation of the agricultural produce to consumption; with regard to commerce, in its conveyance to the consumer; and with regard to the sciences, literature, and the arts, in their power of defending, protecting, and encouraging all kinds of labours, in multiplying the enjoyments of life, and in extending and improving the moral and intellectual faculties of man; services which, notwithstanding their importance, only modify, or transport the agricultural produce, add nothing to its quantity, and yield no new produce; whence they infer, that agricultural labour is the only productive one. This system was not formerly adopted by any English or Italian writer of celebrity; of late years it has met with an able defender in Garnier, a French senator, who translated the "Wealth of Nations" into his own language, for the purpose of writing notes and comments, which he trusted would render the system of the economists triumphant over the doctrines of Smith, and all the writers

who have opposed his favourite opinion. In our country, at a still later period, the economists have found a most ingenious advocate in Mr. William Spence, at least as to their main principle, that the soil is the grand source of wealth. See his tracts, entitled " Britain Independent of Commerce;" and " Agriculture the Source of Wealth to Britain."

In the present state of civilization, we know labour only through the exchange of its produce; in this exchange, every labourer, every family, every nation, find means of supplying their wants, procuring some comforts, and reaching a more or less elevated point of prosperity, power, and happiness. Hence labour appears to contribute to wealth, merely through its produce being exchanged, and by this exchange alone, its particular and general properties ought to be estimated. The value of labour cannot be separated from the exchange of its produce; for if the produce of labour be not exchanged, every individual would be reduced to work to procure the articles necessary for his food, his raiment, and his dwelling; and under such circumstances, ages must roll away, before the unexchanged labour of individuals would produce any wealth. Agricultural labour, then, cannot alone be productive of wealth; and if, like all other kinds of labour, it co-operate in the creation of wealth, merely by the exchange of its productions, if it has no value, but through this exchange, it cannot be called the only productive labour, in opposition to all other kinds.

Of agricultural produce, one part is destined to replace that which has been consumed by the husbandman during his labour; this part has no value of its own, it is merely the instrument of agriculture destined to supply absolute and indispensable wants, and cannot contribute to the formation of wealth. The other, called the net produce, has no value as long as it remains in the hands of the husbandman. His stacks as stock, are no wealth to him; it is only when this net produce departs from him to be consumed by others, that it becomes useful, obtains a value, and forms one of the elements

of wealth. There are only two ways by which this net produce can be transmitted to others, *viz.* by a free gift, or by a cession against an equivalent. "The former," says a good writer, "cannot be practised for any length of time, and has not yet contributed to the wealth of any nation. Hospitality among those who are on the lowest steps in the scale of civilization, benevolence among those who are more civilized, and charity among those whose civilization is heightened by religion, have never been of great assistance to augment the population, wealth, or power of any nation." The second way, the cession of the net produce against an equivalent, alone confers a value upon agricultural labour; but in this case its value is relative, and, like the value of all other labour, is dependent on its being exchanged.

Dr. Smith endeavoured to refute the position of the exclusive productiveness of agricultural labour, by accusing of unproductiveness any labour which, after it is over, does not fix and realize itself in some permanent object; by denying the productive faculty to any labour which does not terminate in a material and permanent produce, and by supposing that wealth depends on the numerical proportion between the individuals employed in what he calls useful labour, and those who are not usefully employed. On this account he wished to reduce the number of labourers who are not usefully occupied, and to increase that of those who are usefully employed; not reflecting, that could this be accomplished to the full extent, the formation of wealth would be impossible, because consumers would be wanting for the commodities produced, and then in future that which was not likely to be consumed, would not be produced. Hence labours exclusively devoted to luxury, pomp, and even the most frivolous expenses, are productive; because they co-operate to increase the population and wealth, and contribute to the splendour and power of states.

The question now occurs, as *to the kind of labour which is most productive*, and most favourable to the growth of wealth. This inquiry is of great importance; it is the

foundation of the science, since labour has the greatest share in the formation, increase, and preservation of wealth. "It is remarkable," says M. Ganilk, "that almost every writer on this controversy has regarded the labour, which is preferred in his own country, as the most productive." Thus, with the exception of Adam Smith, the English writers assign the first rank to commerce and manufactures. In France, where agriculture has always predominated, the writers on political economy have generally granted agriculture the precedency before commerce and manufactures. In Italy, opinions have been divided; and according as they inhabited either the interior or the maritime provinces, the writers on subjects connected with political economy have extolled agriculture, or manufactures and commerce. It may, in this state of things, be worth while attempting to determine whether agriculture, or commerce and manufactures, are most conducive to the advancement of public and private wealth, to the welfare of individuals, the prosperity of nations, and their absolute and relative power; that is, to determine which of these labours obtains the greatest value for its produce on its being exchanged; this circumstance being at once, the promoter, regulator, and arbitrator of wealth.

By means of agriculture, men may succeed in procuring corn and cattle for their food, and raw materials for their clothes and habitations, but here the progress of wealth stops; they would not think of producing any surplus, or of accumulating any stock. Or supposing that a surplus had been stored up, they would have no inducement to cede this to others, to whom idleness or accidents should have rendered it necessary, because no equivalent could be obtained, all agricultural productions being uniform and identic in the same country. But suppose the combined progress of agriculture and population should lead to the division of labour, and the separation of the labouring classes, what, under such circumstances, would be the growth of public and private wealth? As agricultural productions afford the means of subsistence, the wages

of all labour, they would be distributed in proportion to the wants of the husbandmen, and the progress of agriculture; consequently, the share of the industrious classes would be small, and would not allow them to extend, to prosper, or to aspire to a free and independent condition. Supposing even that agriculture could by itself, raise a numerous, rich, and flourishing population, it would not be productive of any great moral and political virtues, of the energy, public spirit, and eminent qualities, which alone form really great nations, and render their inhabitants illustrious. Neither could a mere agricultural nation possess any means of resistance against foreign invaders, of power and grandeur; hence we see the deficiency of the agricultural system with regard to political independence, national power, and public wealth. These defects equally shew themselves in the small extent of general labour, in the insulated condition of individuals, in the weakness of government, and in national impotency and general indifference; of course agriculture cannot be considered as the most productive of all labours, much less as forming "the natural constitution of a government the best adapted to the human race."

Do manufactures and commerce afford the advantages which seem to be denied to agriculture? If it be said that men begin by tilling their lands before they build ships to go in search of new lands beyond seas, it may be answered, that those who are forced to devote themselves to maritime commerce, soon acquire that industry, the offspring of want, which does not stimulate other nations. This industry acquires great superiority, when labour is subdivided, when the manufacturing and trading classes, breaking the fetters which kept them enchained to agriculture, labour, without waiting for the demand, submit their productions to commercial exchanges, and derive from the equivalents obtained in return, their subsistence, their comforts, and their wealth. Their economical notions then take a new course, their relations become complicated; the results of their commerce are lost in an obscurity so profound, that they are not always clear to the

most acute and best exercised understandings, and their advantages and inconveniences are frequently mistaken.

As soon as the labouring classes, whether agricultural, or manufacturing and commercial, carry to market the surplus of their produce above their consumption, and exchange one for the other, general industry receives a fresh impulse, follows another direction, and attains a higher destiny. The producer does not wait for the produce being consumed before he reproduces more; neither does he limit his productions to the local consumption, or to his present and actual wants. In this system, every producer is a consumer; all productions are thrown into the scales of a general exchange, and commerce begets general production by general consumption. The labour of the husbandman is no longer confined to his necessary subsistence; he labours for a surplus, to be enabled to purchase objects, the sight of which, in the market, may inspire him with the desire of possessing them. The industrious do not now wait for orders to labour; they create, invent, perfect the means of rendering life convenient, comfortable, and agreeable; of multiplying enjoyments, and satisfying every desire. They are no longer reduced to a mercenary hawking, but collect and preserve in their warehouses the surplus of productions which have not met with any demand, and endeavour to provide consumers for it on every point of the globe. In this way the trading classes produce, preserve, and multiply wealth.

Riches do not now consist in the proportion of produce to wants, of income to expenditure, of production to consumption: but in the accumulation of a surplus, stored up for unforeseen wants and enjoyments. This surplus is a resource for the existing population against the uncertainty of the seasons, and it acts as a premium for their increase. Individuals are multiplied in proportion to the surplus that is accumulated, and nations prosper in the compound ratio of the mass of their surplus, and the increase of their population, and public wealth results from the exchange of the surplus produce of general labour.

If property, the accumulated surplus of labour, be the spring of labour and wealth, the foundation of social order, and the support of public and private prosperity; how much must its power have been augmented by the abundance of gold and silver, which caused property to reach even the poorest classes of the community, which might be kept or transmitted, stored up, or used, at the call of their passions and dispositions, and according to the circumstances in which they were placed. By diffusing the advantages of property among the labouring classes, the precious metals served as a sort of bond of union, ranking them with the other classes, under the general name of proprietors. Thus greater degrees of civilization were obtained, and the people, otherwise but a few degrees above barbarism, became inspired with sentiments of justice and mutual benevolence. Now the effects which we have described as necessarily resulting from the plenty of precious metals, considered merely as merchandise, belong exclusively to manufactures and commerce, and could not have taken place in the agricultural system; which shews at what a distance those two kinds of pursuit are from each other, and how greatly their reciprocal influence on labour and wealth differs.

In comparing the advantages of agriculture with those of commerce and manufactures, it has been observed, that agricultural produce is common to all countries, and has every where to struggle against a general competition; while commerce and manufactures are peculiar only to some countries and some governments, and have of course no general competition to encounter. Agriculture does not require any great talents; nature performs a large part of the work: its improvements are slow, and the discoveries by which they may be hastened, are soon known to all agricultural nations. The case is different with manufactures and commerce; they require a certain degree of intelligence, are continually improving, reach to a degree of superiority difficult to be attained, and rarely lose the superiority which they have once acquired.

Agriculture is subject to accidents: the risks of industry and commerce are less numerous, and less fatal. Agriculture cannot extend its produce beyond the extent of its territory and agricultural population; neither can it accumulate large quantities of its productions, because they would require immense costly buildings, and because they rapidly perish. Manufactures and commerce may multiply their productions without increasing the number of hands employed, and frequently even by diminishing their number. These productions may be stored up, at comparatively small expenses, in proper warehouses, without any fear of their decaying before they are sold. Their consumption finds no limits but in the numbers of mankind, and in the progress of general wealth; that is to say, it is unlimited. Lastly, agriculture cannot build great hopes on the improvements of its methods. Notwithstanding the encouragements which have been bestowed upon agriculture by governments, and the efforts of learned societies, it has not, among the most enlightened nations, advanced much beyond the point at which it remains among the most ignorant; while the improvements of manufactures and commerce have been uninterrupted within the three last centuries, and promise still greater success from the discoveries of the arts, and the developement of all the productive powers of labour.

Hence it is inferred, that without monopoly, or particular privileges, manufactures and commerce contribute more efficaciously than agriculture to the progress of wealth, and give to manufacturing and trading nations an absolute preponderance over agricultural nations.

Merchants, by following navigators on all coasts, and travellers in all climates, to open commercial communications with their inhabitants, by bringing to market the produce of unknown countries, and in exchange for this, which is of no value to the owners, giving them other useful and agreeable productions, are actually creators both of this new produce,

and the equivalents which serve to pay for it, and augment public and private wealth by the whole value of this produce, and its equivalents. There is, therefore, a kind of industry which is not paid for by local wealth, which draws its wages from the wealth which it creates, and which never can obstruct any kind of manufactures; which can neither be impoverished by, nor impoverish any: all may prosper by each other's side, lend each other mutual support, and be so much the more beneficial to general wealth, as they are more numerous.

The superiority of the mercantile over the agricultural system, is particularly manifest with regard to political power and independence. In the mercantile system, the manufacturing and trading classes are able to spare, for the service of the country, a great number of young men, without any prejudice to general labour. The diminution of workmen is repaired by more exertion, more assiduity, and a better employment of time on the part of the other labourers. And should the produce be diminished, its value is increased by its scarcity, the national income always remaining the same. Even in war, manufacturing and commercial nations find in their foreign relations, in the circulation of their produce in all parts of the globe, and in their credit, facilities, and resources from which agricultural nations are debarred: so that, on the whole, we may conclude, that if labour has the greatest share in the formation and progress of general wealth, its productiveness is not the exclusive lot of any particular labour, but is common to labour in general, and eminently connected with manufactures and commerce. This concurrence of labours is calculated to produce wealth, without any other pre-eminence than that which was obtained by the exchange of productions. By this system, all follow their own inclinations, develope and improve their own faculties, encourage and improve each other by a noble emulation, and are every instant of time reminded of their need of each other. Though scattered over the globe,

speaking different languages, and following different customs, men are no longer strangers to each other; they labour one for the other; they correspond together, although separated by deep seas, severe climates, inaccessible mountains, and inhospitable deserts, and thus the produce of general labour is circulated all over the world.

We are now to inquire into the *causes which invigorate labour, improve its powers, and meliorate its produce.* Dr. Smith ascribes all its improvements to the division of its parts, or the confiding to several hands, the different branches of the same labour, which gives each labourer more dexterity, avoids the loss of time occasioned by the change of labour, and is conducive to the invention of machines which shorten and facilitate labour, and enable one individual to perform the labour of many. On this principle it has generally been considered as one of the things which have most accelerated the progress of political economy, and most contributed to the celebrity of its author. But the earl of Lauderdale has controverted the principle: he contends, in the first place, that the idea of the effects of the division of labour is not new; that it has been recognised from the days of Xenophon; and that on this principle professions in ancient times were made hereditary: he adds, that the great number of distinct operations that contribute towards the formation of some of the most trifling manufactures, is not derived from any degree of habitual dexterity, or from the saving of time, as results of the division of labour, but from the circumstance of performing labour by capital. Without the machinery, which the faculty that man possesses of supplanting labour by capital introduces, no great progress could have been made in the rapidity with which pins are formed; and one man, with the use of this machinery, though he goes through and performs all the operations himself, must manufacture more pins in an hour, than would be formed in a month, or a year, by any number of men among whom labour could be divided, if unaided by the circumstance of part of

their labour being supplanted and performed by capital. The noble earl produces facts in support of his position, and concludes generally, "that it is to the introduction of some sort of machinery; to the effect of the application of chemistry to manufactures; and to the increase or command of capital enabling the manufacturers to reduce the price of manufactured commodities, that we are indebted for the wealth and comforts generally enjoyed by civilized society."

It is of no consequence to the general question whether the effects of the division of labour were or were not known to the nations of antiquity, but it is important to inquire whether machinery, or the division of labour, be more conducive to develope the energies of the labourer, improve his faculties, and increase his produce. The division of labour imparts to the workman not only greater facility, dexterity, and intelligence, to perform the business which he has undertaken, but it distributes every part of the labour in the manner best calculated to hasten and improve its performance: so that if it even were true, that the labourer receives greater assistance from machinery than from the division of labour, yet it would appear, that with regard to labour in general, the distribution of the different parts of labour renders services to it superior to those of machinery. Hence the division of labour appears to be entitled to be compared with the direction of labour. Machines may be more diligent, more active, and less expensive labourers: but the division of labour is the undertaker that directs them, regulates their motion, and guides them to their end by the straighter, and of course, the shortest line. The division of labour prepares the links of that immense chain which connects individuals with individuals, families with families, nations with nations, and converts the whole world into a single workshop,—a general manufactory. If, however, the division of labour be so advantageous in manufactures and commerce, the thing is not at all evident in agriculture.

It is still a subject of debate, whether large or small farms are more beneficial to a country. Dr. Price, in his Reversionary Payments, said there was no maxim of political economy more true than this, that the division of property, that is, of land, into small farms, increased population, and, of course, the strength of the country. Arthur Young, in his Political Arithmetic, assumes, that it is not the number of people, but their wealth, which constitutes power; and that population ought to be subordinate to agriculture, so that the abundance of produce should constantly precede the increase of population. As it is admitted that large farms yield a larger quantity of produce, than they would if divided into small ones, or what is the same, they yield an equal produce at less expense; should this saving of costs be obtained at the expense of the husbandmen, so as to diminish their number, population would not be a sufferer, and wealth would be a considerable gainer.

To inquire into the actual utility of machines, of which Lord Lauderdale speaks so highly, we must distinguish between machines that perform labour beyond the strength of man, and those that perform labours which man is capable of performing. With regard to the former, they are always profitable, and can never be prejudicial, since they afford productions which exceed human strength and dexterity, and could not exist without their aid. With respect to those machines which barely supplant the labour of man, it has been remarked, that they are not prejudicial to nations whose prosperity is on the increase, because they merely supply the want of hands; but nations whose wealth is stationary, or retrograding, have no need of them. This distinction does not seem to rest on any solid foundation, if it be considered that they are not introduced suddenly, but slowly and partially, and the labourer, who through the erection of machines is deprived of his usual employment, likewise obtains his wages from new manufactures, the establishment of which every where follows the increase of productions and

general wealth, and thus the labourer is not likely to suffer by the introduction of machines, whatever may be the state of the country. To this it may be added, that if any thing can arrest the decline of a country, and restore her to prosperity, it would be the use of machinery, and the concentration of small farms into large ones, because they would augment the produce of her labour, and diminish its cost. And wherever there is an increase of produce at a smaller expense, there is an increase of wealth, and an increase of wealth is uniformly followed by an increase of population.

It has been asserted, that wealth acquired by industry may be useless to the increase of the industrious population, and even augment, to their prejudice, the agricultural population, by which they are supplied with the raw produce of agriculture. But in reply it is urged, that an agricultural country increases her raw produce only as far as trading countries insure its sale. The increase of the wealth and population of agricultural nations depends, therefore, on the industry and population of the manufacturing ones. But in what proportions does the increase of wealth and population take place in both countries? It has been said by Garnier, that one day's labour in the manufacturing country, is equivalent to two or three days' labour in the agricultural country; therefore, while the wealth and population of the agricultural country are increased in the proportion of one to three, the wealth and population of the manufacturing country augment in the proportion of three to one. Again, the raw produce of an agricultural country is not by any means so well calculated to increase population as a manufactured produce; for the raw produce does not remain with agricultural nations; it passes over to the manufacturing nations. This raw produce is food for population, while the manufactured produce serves at the most as raiment and household furniture to agricultural nations. In this exchange of food for garments, the population that gets the food in a triple proportion to that which gets clothing, must necessarily increase in a triple proportion;

because it is food and not clothing which augments population. This result, which cannot be disputed, ought to teach agricultural nations the necessity of turning their attention to manufactures and commerce, on account of their superiority over agriculture.

The inference deducible from what is gone before is, if our reasoning be conclusive, that the means of increasing the power of labour, of augmenting its produce, and meliorating its quality, consists, with regard to agriculture, in large farms; and with regard to manufactures and commerce, in the division of labour and the use of machinery. These means give to labour the highest degree of utility which it is capable of attaining, particularly if their effect be not impeded or destroyed by various obstacles, so much the more fatal as opinions are divided concerning their influence. These obstacles, said by some philosophers to be prejudicial to the progress of labour, and by others considered as beneficial, are the slavery of the labourer, apprenticeships, corporations, and low wages. On these subjects we cannot enlarge, but shall give certain statements illustrative of the subjects, chiefly taken from some admirable papers published in the beginning of that useful and respectable work entitled the "Monthly Magazine," by the late Mr. J. J. Grellier. Assuming from the parliamentary returns, the population of Great Britain, including the army and navy, at 10,820,370, he endeavoured to distinguish, as nearly as he was able, the proportion of those who subsist by the labour of others, to those by whom they are supported; and of the unproductive, though, in most instances, useful labourers, to those on whose labour the annual produce, and consequently all additions to the national stock, depend.

It appears, that of the whole number of persons living, more than one-fourth are children under ten years of age, who therefore contribute little or nothing to their own maintenance; for though in a few manufactures, children under this age are employed, they are more than counter-

balanced by the greater number who remain unemployed for several years beyond the age of ten. After deducting 2,705,092, it will be found, that one in about 28 of the remainder, or 289,831, are incapacitated by old age or infirmities from useful labour, including all persons in hospitals, &c. and most of the inhabitants of alms-houses, and other charitable establishments. But of those who are supported by the labour of others, or by the property of others, which comes to the same thing, there are many who follow a species of employment, by which they obtain this property, which employment is, however, of no benefit to the country, as it is not only unproductive, but useless, and in many instances injurious to the community; such are gamblers, swindlers, thieves, prostitutes, beggars, gipsies, &c. whose aggregate number, according to Mr. Colquhoun's estimate for the metropolis, probably exceeds considerably 150,000. The convicts and prisoners confined in the different prisons of Great Britain, and on board hulks, are usually about 10,000 persons, whose labour is lost to the community, for the work which is performed in some of our gaols scarcely deserves mention. There is also a class of a very different description, who are supported by the labour of others: this is the nobility and gentry, whose exemption from labour is considered as a part of their honour and distinction; some, it is true, hold employments under the government, and a few are engaged in agriculture or trade; but the majority, who subsist on the income they possess, without following any useful occupation, is probably not less than 5000.

These numbers include persons of both sexes, and are all rather below the truth than beyond it; they amount together to 3,159,923 persons, and being deducted from the whole population of 10,820,370, shew the number of those who work to be 7,660,447. But it is well known, that of those who gain a subsistence by their labour, many follow employments which, though more or less necessary and useful, do not, in the least degree, increase the quantity or value of the

produce of the country; the number of these unproductive labourers is reckoned 1,704,500.

The whole population of the country, without going into the particulars, will consist of nearly the following proportions:

Supported by others' labour - - -	3,159,923
Unproductive labourers - - - -	1,704,500
Productive labourers - - - - -	5,955,947
Total -	10,820,370

It thus appears, that the whole of the people depend for subsistence, and all the conveniences of life, on the labour of little more than one-half; and the increase or decrease of this number, and of the effect produced by the individuals who compose it, is the measure of the increase or decline of national strength. Of the unproductive labourers, or those who gain a subsistence by defending, instructing, or serving others, the greater part are highly useful to the community, and in the present state of society a nation could not exist without them; but as they do not contribute to the production of any of the necessaries of life, or articles of commerce, it is evident that they depend entirely on the exertions of the productive labourers, who are the source not only of the general subsistence, and of the means of commerce, but of all accumulation of stock, which is, in fact, the surplus of former produce beyond the consumption. The power of acquiring national wealth, therefore, depends principally on the proportion of productive labourers to the whole number of inhabitants; for though the population of a country should have greatly increased, if it be chiefly by an addition of idle hands, the produce would remain the same, and, the consumption being much greater, the country must become poorer: but it likewise depends, in a great measure, on the facility with which labour is performed; for if a country contained only half the number of labouring inhabitants, with the

same number of other persons it had at a former period, but this half, by means of machinery and other improvements, could produce the same effect as the whole number before, such a country would become considerably richer, though the total population was diminished, and the proportion of unproductive to productive persons increased: for there would be the same supply and a much less consumption; and wherever the produce or supply exceeds the consumption, there will be an acquisition of stock; for, unless the surplus could be reserved for some useful or desirable purpose, it would soon cease to be produced, by the supply falling to the level of the demand for consumption. The surplus reserved, or converted into stock, is a fund for supporting an increase of exertion, or for supplying the means of future enjoyment.

We now proceed to consider another important subject in the science of political economy, *viz. the various systems concerning capital.* On this topic, the theory of Dr. Smith is, without dispute, new. The subject, before his time, was not at all understood. The writers on political economy made capital consist entirely of metallic currency, and derived it from foreign commerce; hence their system was denominated the mercantile system. The French economists, who substituted the agricultural system, acknowledged no other capital than the advances on cultivation. Dr. Smith took a larger view of the subject; and capital, according to his theory, consists in the advances and prime materials of all kinds of labour —in the improvements of soil—in the implements and machines for the purposes of agriculture, manufacture, and trade, which, of course, comprise both metallic and paper currencies—and likewise in commodities reserved for general consumption. The latter may fairly be objected to, though our limits do not allow us to enter on the subject; yet it cannot but be matter of surprise, that the doctor should enumerate with capital, commodities reserved for consumption, and incapable of being accumulated. Some modern French authors assign to land, mines, and fisheries, which they regard as instruments of pro-

duction, the rank of capital; but lord Lauderdale limits capital to the instruments and machines adapted to shorten and facilitate labour. The author to whom we have frequently referred, M. Ganilk, defines CAPITAL to consist *in the accumulation of the produce of labour;* and he adds, that "according to this definition, lands, mines, and fisheries, in their original state, would not be comprised among capitals; and stripped of the improvements, instruments, and machines which render them productive, they scarcely deserve to hold a place in the capital stock of a nation. Their spontaneous produce is but the smallest part of the general produce of labour, and cannot contribute any separate article in the wealth of nations. If we deduct from agricultural produce the part which is due to cultivation; from the produce of fisheries, that which is due to the implements and tools for fishing, and particularly to the art of salting, drying, and curing fish; and from the produce of mines, that which is due to the aid of machines and extraordinary labours; there remains so little, that there is no danger of erring in ranking them among the produce of labour, and admitting them only as such among capital."

Capital offers three different considerations, equally interesting to the science, to its progress, and to its results; *viz.* its *formation, employment,* and *influence* upon public and private wealth. According to Quesnai, capital is derived from economy in the costs of agricultural labour; from the savings in the expenses of the land-owners, as far as those savings are applied to improve the soil; and from the increased price of commodities through foreign trade: and, therefore, nothing contributes to the formation of capital, but the saving of the net produce, when employed in agricultural improvement. And Dr. Smith derives capital from the greater or smaller quantity of productive labour relatively to unproductive labour; from the proportion of the productive to the non-productive consumers; and from economy in private consumption: and he adds, *capital is*

increased by parsimony, and diminished by prodigality and misconduct. In one principle, Quesnai and Smith agree, the one faithful to the agricultural system, and the other to his system of productive labour; they both regard nothing but the savings applied to agricultural or productive labours as proper to form capital. In whatever way economy may be effected, it leaves at liberty a sum of produce which is consumed by the idle, or by the labouring classes. If by the latter, it serves to pay for more labour, or for useful labour to be better done. Increased or improved labour gives more or better productions, and consequently more wealth. Higher wages, at the same time, procure more comforts to the labouring class; and more comforts become the cause of a greater population. Thus the savings consumed by the labouring classes evidently increase both wealth and population. When the savings are consumed by the idle classes, they serve to employ a greater number of individuals in labours of luxury: and it matters little whether the savings be made by the idle classes, or whether they be borrowed by them from the labouring class. In the first case, the savings serve only to augment the population; in the second, the savings of the labouring class are exchanged for the capital of the idle classes, and this exchange is not at all injurious to the national capital; it simply effects a change of capitalists, which is perfectly indifferent to the formation of capital and wealth, and is in no-wise prejudicial to population. It seems, therefore, clear, that Quesnai and Dr. Smith were mistaken in assuming that savings cannot contribute to the formation of capital, except they are applied to agricultural or to productive labour. They clearly contribute to the formation of capital, though they are employed in labours of luxury. This kind of labour, the least beneficial, indeed, to wealth, constantly and infallibly replaces the savings by which it is paid, and constantly produces the population which is maintained by these savings. Hence it is given as

an axiom, that *capital is always derived from economy, and can neither be formed nor increased otherwise than by economy.* This system has been opposed by the earl of Lauderdale, who makes the property of a society chiefly occupied in agriculture, to consist in the land which it cultivates—the stock it reserves for immediate and remote consumption—and the *capital,* which consists of the animals or machines which are employed to save labour in the cultivation of the land, or in the convenient consumption of its produce. If, however, wealth result from the accumulation of the surplus of the produce of labour over consumption, it may certainly be increased by other means than by those mentioned by the noble lord, *viz.* by economy, which he seems to hold in contempt.

Suppose a nation accumulate a certain sum annually, it is either distributed to individuals, whose situation is rendered more comfortable, and who pay for it with more or better labour; and in this case it acts as an encouragement to labour and industry, and multiplies the means of public and private wealth; or it is given to individuals taken from the labouring and industrious classes, to be employed in the service of the idle and rich: in that case also it increases population by all the individuals it maintains. Such is the natural effect of economy, and of an increased produce; both contribute to the progress of population and wealth. There are no limits to this progress, but in the utmost extension and improvement of agriculture, manufactures, commerce, population, and civilization all over the world. People, therefore, ought never to relax in endeavouring to increase their produce, and being economical in their consumption. It is certain that consumption is the measure of production, for a produce that finds no consumer, is not long reproduced. It must not, however, be inferred, that an abundant, and even an over-abundant produce is not consumed. The abundance of productions is always an excitement to a greater consumption; and, as abundance

is wealth. Wealth in its turn affords the greatest possible means of consumption. Production is limited by consumption, either when the consumer does not like the commodities produced, or when he is unable to pay their price. The producer is every where obliged to consult the taste and faculties of the consumers, and it is when he is mistaken in these two respects, that non-consumption is detrimental to reproduction. Produce will always be consumed, provided it suits the consumers, and they have the means of paying for it. Abundance and cheapness are the springs of consumption and reproduction; and as economy necessarily produces both, it follows that economy is beneficial to both.

We are now to inquire in what manner capitals are *employed*. M. Quesnai mentions the following ways: 1. In the original advances, which have cleared the ground: 2. In the annual advances, which reward the labour of the husbandmen, preserve the original advances, and provide against accidents: 3. In the advances which serve to pay for the raw materials and wages of labour: and 4. In the advances of the merchants, who defray carriage and warehouse expenses. Dr. Smith took a more enlarged view of the subject; he devotes one part of the capital to immediate consumption, consisting of food, clothing, household furniture, houses, &c.; a *second* part he calls fixed capital, which affords a revenue without circulation, or changing masters; this consists in useful machines, which abridge labour—in buildings, that procure a revenue not only to the proprietor, but to those who pay rent for them—in the improvements of land—and, lastly, in the talents of all the inhabitants of the society. The third and last portion is the circulating capital, and is composed of money—of the stock of provisions, from the sale of which a profit is expected—of materials, whether rude or partly manufactured—and fourthly, of work ready for sale, but not disposed of.

The difference of opinion between M. Quesnai and Adam Smith, is the consequence of their different theories concern-

ing the source of wealth; which the one places in agriculture, and the other in any labour which fixes and realizes itself in some permanent object.

That part of the capital stock which Adam Smith denominates the circulating capital, is nearly the same with that which M. Quesnai calls annual advances. Both intend this part of the capital stock of a country to provide for the divers wants of agriculture, of manufactures, and commerce; they only differ in so far as Adam Smith admits the metallic currency of the country into the circulating capital, which is not mentioned by Quesnai. But the theory of circulation, of which a metallic currency is the principal instrument, had made but small progress at the time the French economists wrote, and its benefits could not easily be foreseen; nor its extent, resources, and results calculated.

Dr. Smith says, that the metallic currency of a country forms part of her circulating capital, and is not only of no benefit to wealth, but even burthensome to it as an object of expense. Some writers on this subject imagine, that money operates in the same manner as other machines employed in agriculture, manufactures, and commerce; and tends, like them, to shorten labour, and is productive of whatever the exchange of commodities costs, less than what it would have cost without the assistance of money. Of this number is the earl of Lauderdale, who has treated the subject in a very luminous manner; and who explains, by a novel and ingenious method, the operation of money in the interchange of the produce of labour. For his lordship's reasoning and illustrations on this subject, we must refer our readers to the third chapter of the "Inquiry into the Nature and Origin of Public Wealth." Money, says the noble lord, is of use to mankind in two different capacities, as an instrument of exchange, and as a practical standard, by which the value of all commodities is measured and expressed: it will be easily understood how this part of the national capital employed in these two duties is profitable when we

reflect, what would be the effect of withdrawing from any society, that part of the capital which is employed in conducting the circulation of goods, and in forming a practical standard by which the value of commodities is measured; for the moment this portion of the national capital is abstracted from any society, the exchange of those things which one man produces with greater ease, for those which another can produce with more advantage, must be conducted by barter. Thus, if a farmer who had more wheat than he wanted, and who meant the surplus to supply his family with other necessaries, wanted a pair of shoes, he must carry a portion to a shoemaker, in order to negociate an exchange, but the shoemaker is already supplied with as much wheat as he wants; the farmer must then either seek another shoemaker, or ascertain what articles of consumption the first wants, in order to make a third or fourth exchange before he could get his shoes. This singular instance, which any reader can easily conceive and follow into all its consequences, will explain the labour that must attach to every person, if the circulating capital of a country were obstructed, in endeavouring to supply his wants by parting with his own superfluities. Thus coin, employed as a circulating capital, has been eagerly sought after, not for its own sake, or for the sake of the gold and silver it contains, but merely on account of the labour it supersedes. It not only, however, requires a certain portion of labour to acquire, but also to carry about when procured. To prevent this, various modifications of banks have been introduced. Hence the question, do bills of exchange, paper-money in general, and public stocks, form capital; and if so, are they part of the *fixed* or *circulating* capital? They seem entitled to be regarded as capital, because they perform the functions of capital; on the other hand, they ought not to be regarded as capital, because they have no value of their own, and only represent a mortgage, which itself constitutes a part of capital. Bills of exchange represent the merchandize which

they cause to circulate. The mortgage of private promissory notes, consists in the moveable and immoveable goods of the debtor; and public funds or stocks have their mortgages in a particular branch of the revenue. This merchandize, these moveable and immoveable goods, and this branch of public revenue, constitute part of the *fixed* capital, of the *circulating* capital, and of the *stock* reserved for immediate consumption.

Capital stock, considered as *fixed* capital, as *circulating* capital, and as capital destined for immediate consumption, provides for the wants of labour, contributes to its progress in proportion to its own increase, and always affords an exact measure of the progress of national wealth. There is a fourth employment of capital, by its being lent out to interest, either to private individuals or to the public. Writers on political economy are not agreed respecting either the utility or disadvantages of this kind of employment of capital. For the various theories on the subject, we refer to the works of Dr. Smith and M. Ganilk.

We shall now briefly consider the various systems relating to the circulation of the produce of labour by means of commerce, which is the only method by which nations attain wealth, splendour, and power. "Trade," according to Dr. Davenant, "is the living fountain whence we draw all our nourishment. It disperses that blood and those spirits through all the members, by which the body politic subsists. The price of lands, value of rents, manufactories, &c. rise and fall as it goes well or ill with our foreign trade." "The greatness of a state, and the happiness of its subjects are," says Mr. Hume, "generally allowed to be inseparable with regard to commerce." M. Quesnai observes, "Like sale, like production." An able Italian writer on political economy, M. Genovesi, says, "The end of social economy is, 1st. increased population; 2d. wealth; 3d. natural and civil happiness; 4th. the grandeur, glory, and welfare of the sovereign. Of all means of attaining this

end, there is not one more efficient than commerce, which avails itself of human avidity, as the most powerful promoter of all social advantages." To these testimonies in favour of the circulation of produce, by means of commerce, we may add that of our countryman, Dr. Adam Smith. "As it is the power of exchanging, that gives occasion to the division of labour, so the extent of this division must always be limited by the extent of that power, or the extent of the market." Hence the importance of commerce, or of the circulation of the produce of labour. In this point all writers on political economy are unanimous; but with regard to the principle, nature, progress, and effects of this beneficial circulation, opinions are very various. The origin of commerce is sought for, by, some, in the avarice of mankind; by others in their propensity to barter and exchange one thing for another; and by others, in their variety. The same sort of uncertainty prevails respecting the laws which determine the respective value of the produce exchanged by commerce, concerning the influence of money and credit upon commerce, and concerning the most useful and profitable mode of commerce.

Without attempting to decide upon the origin of commerce, we may observe, that no one parts with the produce of his labour, and puts it into circulation, but in the expectation that it will procure him more food, or greater conveniences, comforts and enjoyments: hence the farther circulation extends, or the larger the market, and the more that market offers varied productions and new enjoyments, the more does labour increase in intensity and activity, the more is its produce multiplied, and wealth enlarged and augmented. The sources of the circulation of the produce of labour may be traced in the passion for enjoyment, in the efforts of commerce, and in the genius of the arts. To their united action commerce owes its impulse, its progress, and its success.

The value of produce is regulated by the wants of the consumers, and their means of supplying them; by the demand for commodities, and their abundance and scarcity; by labour,

&c. Most writers on this subject are of opinion, that things have no other value than what is fixed by the demand for them, and their abundance or scarcity. One writer observes, that the words *price, worth, value,* are relative terms, because things have no price or value but relatively to man: wherever there are no men, there are no values; but man assigns no value to things, but as he wants them. By another person it is said, that the sole capability of being exchanged, combined with the greater or smaller natural abundance of things, and with a more or less ardent desire to be possessed of them, forms the basis of what mankind denominate value. The price of things, according to another author, is composed of two elements—their utility and their scarcity: of course their value increases with their scarcity, and diminishes with their plenty. Dr. Smith observes, "that the value of any commodity to those who possess it, and who want to exchange it for some new production, is precisely equal to the quantity of labour which it can enable them to purchase or command: whence he infers, that labour is the real measure of the exchangeable value of all commodities." The earl of Lauderdale opposes this doctrine. He maintains, that a perfect measure of value is impossible; for as nothing can be a real measure of length and quality, which is subject to variations in its own dimensions; so nothing can be a real measure of the value of other commodities, which is constantly varying in its own value. But things may alter in their value in three different ways: 1st, in respect to different periods of time; 2d, in different countries; 3d, in different parts of the same country. Labour is not only subject to all the usual sources of variation, but possesses the characteristic of varying at the same time and place: hence labour cannot be a standard. Money and corn are not better calculated than labour to fix the value of things for distant times. As then the value experiences a rise and fall perfectly similar to the rise and fall of the price of commodities, and as this variation in their respective values proceeds from the same cause, that is, from the proportion of

the demand to their abundance or scarcity, there is no difference between their values: both are alike liable to vary, and consequently both are alike unfit to form an invariable measure of value; so that it is the exchangeable value which ultimately gives to every producer the equivalent of what his commodity cost to produce, and consequently secures the producers against loss. Beyond this, the profits on the productions of labour are unequal. This inequality of profits is indifferent with regard to home-trade: for the superiority of certain labours and employments of capital cannot be of long duration, because those which are least favoured go over to the most favoured ones, and by their competition re-establish a certain proportion between the profits of all labours and employments of capital. But it may be asked, is the inequality of profits in the exchange of home for foreign produce equally harmless? The question has been ably discussed, and decided affirmatively, with the observation, that there is but one motive that should induce a nation to prohibit the importation of the produce of other countries; that is, when the government of our own country is so defective, that none of our home productions can stand a competition with foreign productions, even in the home market; when national industry is not capable of being stimulated by the rivalry of foreign industry; and when the people abandon themselves to sloth and misery. With this single exception, foreign commerce, or general circulation, is beneficial, useful, and profitable to all, and contributes, if not with equal, at least with certain, success to the progress of wealth.

CHAP. XXV.

POLITICAL ECONOMY,

Continued.

General observations on the mercantile system—Money—Taxes on the rent of land—On the wages of labour—On consumable commodities—Various systems concerning national income and expenditure—Population—Dr. Smith's theory—Malthus's Essay on Population—Progress of Population—Tables—Brief notices on other topics of Political economy—Method of studying the subject.

THE fundamental principle of what is called the mercantile system is, that wealth consists in money, in gold and silver. The facility of exchanging these metals for any other commodity, the habit thence derived of calculating the wealth belonging to each individual, has made this a natural as well as a general error.

The exchange of one thing for another of equal value, is essential to the supply of the varied wants of man. Thus it is, that men, while merely consulting their own interests, minister to each other's necessities. It is, however, attended with an obvious inconvenience. A man may have goods to exchange, which do not suit his neighbour. The farmer has a sheep, and is in want of cloth, but the cloth manufacturer may not be

in want of mutton; hence the necessity of finding some commodity which may be at all times in demand, and which every one may be ready to receive in exchange for every other article. This commodity ought to possess some quality which may render it an object of universal estimation. It ought also to possess considerable value in a small compass, so as to be portable: it ought to be divisible into the smallest portions, and it ought to be durable, so as to be capable of being treasured up till wanted. These qualities are united in the precious metals, and therefore they are better suited than any other commodity, for being the standard value and medium of exchange, and all nations have sooner or later had recourse to them for this purpose. Hence we may consider money as the universal merchandize, that is, the merchandize which, on account of the smallness of its volume, renders it easy of transportation; and on account of its divisibility and incorruptibility, is universally acceptable, and taken in exchange for any other merchandize.

"In all civilized nations," says Dr. Smith, "money has become the universal instrument of commerce, by the intervention of which, goods, of all kinds are bought and sold, or exchanged for one another." Reduced to its true nature, that is, considered as a preferred commodity, and, as such, as a general instrument of commerce, money has been released from that dependent and arbitrary state to which it had been too frequently exposed, and is safe against all financial and fiscal operations. As a produce of labour, money has an exchangeable value, which, like every thing else, is determined by the demand for it, and by its abundance or scarcity. As a preferred commodity, it has a higher exchangeable value, for which it is indebted merely to the nature of the metals of which it is composed. Public authority, which by its stamp, confers upon it the character of legal money, adds nothing to its value, and can give it no other value than what commerce confers upon it.

In one view money is a fixed, and in another a circulating

capital. To the individual it stands in the latter capacity; for no one receives money unless for the purpose of sooner or later exchanging it for something else. To the nation it is a fixed capital, not destined for consumption, but merely an instrument for transacting business with greater facility and advantage. As the facility of exchanging the precious metals for every other commodity, renders the demand for them constant and universal, their price depends almost wholly on the supply. Therefore although the functions of money, like those of other fixed capitals be most essential to the maintenance of trade, yet if any less costly substitute can be found, by which the same functions can equally well be performed, the public is a decided gainer. Such a substitute is in fact paper-money; by employing which a nation saves the expense of gold and silver, and at the same time obtains all the commercial advantages which money could effect. It is even in some respects more convenient, as being more easily transportable, and less liable to accident. There are, however, very extraordinary dangers attending the excessive and incautious use of this instrument; and no cause perhaps has been productive of more signal commercial disasters. The apparent facility of thus creating wealth, as it were, tempts banks and other public bodies to an excessive issue of it. The circulation of the country, however, can absorb only a certain quantity; and as soon as that is thrown in, it immediately returns upon the issuer, in a quantity for which he is probably unprepared: and the instant he shews the least hesitation in discharging the demand, the whole rushes in, and bankruptcy and ruin ensue. Where the paper has been issued by government, payment may be refused; but in this case an immediate depreciation takes place in the value of the notes, and a deep injury is sustained by all who are possessed of them. From this cause it was that the French assignats, in the early part of the Revolution, fell so far below their original value, as scarcely to be worth the paper of which they were formed. There may, however, be peculiar circumstances which produce a scarcity of money, and in which a temporary

suspension of payment may become necessary, and with due caution, may be productive of no very alarming and serious consequences; such in truth was the case with the bank of England in 1797.

Banks, however, ought not to advance to merchants the whole capital on which they trade, but only that part of it which they would otherwise be obliged to keep by them for the purpose of answering occasional demands. This they do only in two ways, unless they themselves become speculators, from which they should be restrained: 1. By discounting bills. 2. By granting what are called in Scotland cash-accounts: that is, two persons of, or of supposed respectable property, become responsible to the extent of a certain sum, and the merchant is allowed to draw to the extent of that sum. Merchants, do not, it is well known, content themselves with this limited degree of assistance: they too frequently carry on extensive speculations merely on paper money. For this purpose they draw fictitious bills for the mere purpose of having them discounted; and by drawing a second before the first becomes due, they delay still farther the repayment of the original advance. Banks should always, if possible, avoid discounting fictitious bills: and should take care, in cash accounts, that the advances and repayments nearly keep pace with each other: in this case there can be no great danger of an over issue of notes.

Having been led to say thus much on money, on which we might easily fill many chapters, instead of a page or two, we may proceed to observe, that, to *export much*, and to *import little*, has, according to the mercantile system, been thought the great means of enriching a nation. The difference between exports and imports was called the *balance of trade*, and considered as the grand criterion of commercial prosperity. If the exports exceeded the imports, it was called a favourable balance; if, on the contrary, an unfavourable balance. To accord with this theory every expedient was adopted which might diminish importation, and encourage exportation in

general, and particularly in regard to those countries with whom the balance was unfavourable. Hence arose:

1. Restrictions upon the intercourse with a particular country, which is supposed to have a balance against us. These, however, are unreasonable: for if we get commodities cheaper from that nation, and sell ours to greater advantage, the balance will, on the whole, be more in our favour than if we carried on similiar transactions with any other nation.

2. The whole idea of the balance of trade is now generally regarded as chimerical. By every exchange which takes place with a foreign country, the nation gains as well as the individual; nor does it make the smallest difference whether goods or money be received in return. As the principle of the mercantile system naturally leads to the supposition, that whatever is gained by one nation is lost to another, it generally leads to violent commercial jealousies between neighbouring countries. It also, through ignorance, happens, that the nearer the commercial countries are to each other, the more are restrictions and prohibitions multiplied: whereas, in truth, the nearer to each other, the more advantageous is their trade. It approaches the more nearly to the home trade, in the quickness of its returns, and can be carried on with a smaller capital. The plan, therefore, of making our neighbours as poor as possible, is completely unwise. The richer they are, the better customers they are likely to become, and the greater benefit we shall probably derive from their trade. With regard to the subject of restraints upon importation,—and encouragements to exportation,—of Corn Laws,—of exclusive companies, and of Colonial Policy, we must refer to Dr. Smith's Wealth of Nations, and we shall proceed to some observations on the Public Revenue.

As the whole society derives from government its protection against evils internal and external, the regular administration of justice, and a variety of other benefits, without which it could not subsist, it is perfectly equitable that each individual, in proportion to his means, should contribute to the extent which is necessary for fulfilling these different objects.

Regular government is even indispensable to the production of public wealth, as it alone affords that security of property which is the life of industry. In this view the officers of government cannot be considered as unproductive labourers, but might more properly be regarded as part of the fixed capital of the country.

With respect to *taxes*, raised for the support of government, there are four circumstances, which ought, as far as possible, to be kept constantly in view, and the observance of which forms the criterion of the propriety or impropriety of each particular tax. 1. They ought to fall as equally as possible on every member of the society, in proportion to his means of contribution. For as all derive equal benefits from the establishment of regular government, all ought to contribute equally for its support. It should however be observed, that the rich not only should contribute more, but in greater proportion, than the poor; as the greater part of their expenditure is on luxuries, they can retrench a part of it much better than those who, to pay the tax, must be deprived of some of the necessaries of life. 2. The sum paid by each person ought to be fixed, and not left to the arbitrary appointment of the collecting officers, whether of low or high degree. 3. A tax ought to be payable at the time when a man can best afford it. 4. In proportion to what it brings into the treasury, it ought to take as little as possible from the people, that is, the expense of collection ought to be as moderate as possible.

The *rent of land* has always been considered as a proper object of taxation; it comes to the possessors without care or trouble, and it depends more than any other source of income on the protection of government. The rent of houses is of a very different nature. Houses are produced by art; and as the builder must have his profit, the rent will be raised in consequence of the tax. The rise, however, does not take place immediately, because houses are so durable, that for some time there will be no diminution of the supply, the rent will continue the same, and the loss will fall on the

proprietor. As, however, a certain number of houses fall to ruins, builders will not continue their business without adequate profits; of course the rents will rise to their proper level. Taxes are sometimes imposed, not on rent, but on the produce of land; such are tithes, which are extremely pernicious, as they discourage industry; and hence it would be of great public advantage, if tithes were commuted for an annual sum, as it would, in that case, be completely and entirely the interest of the farmer to raise as much produce as possible.

The French economists contend, that all taxes ultimately fall on the rent of land, and therefore they say that they should be laid directly upon that, because they assume that taxes cannot fall either npon the profits of stock, or the wages of labour, which however does not seem to be the case. For the profits of stock may be divided into three parts, the *first* is equal to the *market rate of interest*, that is, what any one would be willing to give for the mere use of the stock;—the *second* is the compensation for the *risk* incurred;—the *third* is a compensation for the trouble of carrying on the business. Of these the *last* seems to belong to the wages of labour: the *second* is certainly not taxable, because a man would rather not employ his stock at all than not receive a full compensation for the risk he runs in so doing. The *first*, which alone ought, perhaps, to be considered as the profits of stock, is almost to its whole extent, completely taxable. Although, out of *five* per cent. government should seize upon *four*, it would still remain the interest of the capitalist to lend, or employ his stock, rather than lose the remaining *one*. After all, the profits of stock are less a subject of taxation, than the rent of land, because they are not so easily ascertained. The capital from which they have been derived has been accumulated by industry and frugality; and it is the interest of the public to encourage this accumulation.

Taxes on the wages of labour. Dr. Smith says, that no tax can fall upon the wages of labour: that wages would

in consequence of such taxes, instantly rise; and that the only effect would be a rise in the price of every species of produce. To which it has been replied, that a tax on the wages of labour has no tendency to increase the funds for the maintenance of labour, but to diminish them. The supply and demand will be the same. The only way in which such taxes can raise the price of labour, is by diminishing the supply of it, that is, the population, which in time it is likely to do. Such taxes are therefore oppressive, and ought to be avoided.

A well regulated *Income Tax* is, in many respects, the most equal which can be imposed. It falls upon every man according to his ability; and the expense of collection is small: but it is liable to many serious objections: it demands a disclosure of private circumstances, and it affords much room for evasion. The advantages and disadvantages attending an Income Tax, are well argued in the New Annual Register, for the year 1815.

Of all taxes, those on *Consumable Commodities* are the least felt; being paid directly by the merchant, they are felt only in the increased price of the goods, which every one has the power of paying or not as he chooses. But no taxes take more out of the pockets of individuals, in proportion to what they put into that of government. The tax being advanced by the merchant, he expects not only to have it repaid him in the price of his goods, but to have it repaid with a profit. Such taxes may be laid either on the necessaries or luxuries of life: the former are avoided as much as possible by all wise legislators, as oppressive, falling chiefly on the poor, and having a tendency to raise the wages of labour.

Of the various systems concerning national income and consumption. All systems of political economy agree in making national income to consist in the produce of annual labour. The spontaneous productions of the soil, of mines, and of the waters, are not very considerable, and moreover require a certain portion of labour to be brought to market. Income is either private or public. The produce of general labour, whether in the hands

of individuals, where it forms private income, or diffused all over the country in the shape of national income, is partly consumed by the producer, and partly exchanged with the view of consumption. If the produce, consumed in the place where it was produced, be abundant, its plenty contributes alike to public and private wealth; but if that produce be rare, its scarcity impoverishes the individual and the public. With regard to the produce exchanged by the producers, if the exchange take place with a foreign country, its abundance turns it to the benefit of the foreigners, who purchase it with the same values which they used to give for it, unless the foreign country should have been favoured with a like abundance in its own produce; because in that case plenty is equally beneficial to the foreigners and natives, and in both cases private and public wealth remain the same. But if the produce exchanged with the foreign country be scarce, the foreigners are sufferers by this scarcity. Finally, if the exchange of national produce take place at home, its plenty becomes beneficial to the consumers, without loss to the producers, because the latter always receive the same value which they usually received from the consumers. But in case of scarcity, the loss is to the consumer, yet without any benefit to the producer, because the consumer can only give him the usual value: therefore in both cases there is neither loss nor profit for private and public wealth. But when the abundance or scarcity is excessive and extraordinary, it is more or less fatal to the producer or consumer, still without effecting any difference between public and private wealth, because what the one loses, the other gains: and public wealth, which consists of individual riches, experiences no change from the loss of the producers and the gain of the consumers. It seems to be of great importance that governments should be fully convinced of the identity of public and private wealth, because it is on this truth that the maintenance of social order, the progress of public wealth, and the melioration of mankind do, in a great measure, depend.

The produce of annual labour, whether considered as private or national income, is distributed in the shape of wages of labour, profit of stock, or rent of land; and the distribution is regulated by the progressive, stationary, or retrograde state of national wealth. When wealth is progressive, more produce of the annual labour is distributed in wages of labour, profit of stock, and rent of land: when it is stationary, a smaller quantity of that produce goes to the labourers as wages, and to the landholders as rent; and the profit of stock remains as before; but when it is retrograde, the wages of labour sink so low, that they are scarcely adequate to supply the most urgent wants of the labourers; rents also suffer a considerable diminution, but the profits of stock experience a rise corresponding with the decline of national wealth.

Consumption bears a necessary and indispensable proportion to the national income, but that proportion has not yet been invariably fixed. The French economists think that consumption ought to be equal to the income, and they allow no economy but in that part of the annual income reserved for the land-owners as the net produce of their lands. But according to Dr. Smith, consumption ought to be inferior to income, and it is on the surplus of income that he chiefly founds the progress of national wealth: and he assumes that parsimony, and not industry, is the immediate cause of the increase of capital. There are some authors who condemn economy; who regard consumption as the measure of reproduction; and maintain that the people are the richer the more they spend, whence luxury would become the most powerful spring of wealth. When an individual consumes more than his income, the surplus must be taken from his capital, which is gradually diminishing, and the diminution of the capital diminishes his income in the same proportion: and if he go on upon this plan, the time will come when that individual, having neither income nor capital left, will be obliged to labour for his subsistence, or to be indebted for his maintenance to public charity. What is true of one individual, is equally so of several, and

even of a whole nation, and the excess of consumption above income may therefore occasion the ruin of nations, as it does the misery of individuals. It was so understood among the ancients, who not only recommended economy, but honoured parsimony very highly, and imputed to luxury the decay of morals, the loss of private fortunes, and the ruin of the state. A distinction ought, however, to be made between individuals and the state; for though the expenditure of individuals should absorb their income, it may, so far from being prejudicial to national wealth, even contribute to its increase. The desire of comforts, the love of pleasure, &c. are powerful incitements to labour, and induce the labourer to multiply the produce of his labour; and in that case he labours more in proportion as he consumes more, and he becomes richer as his expenses are more considerable. In this particular instance those are right who praise luxury, and attribute to it a large share in the increase of wealth, and also in the civilization of individuals and nations; but neither individuals nor nations can enjoy a solid and permanent prosperity, unless when private and public consumption does not absorb the general income, and when the surplus produce, that is annually accumulated, goes to augment the sum of labour, raise the wages of labourers, increase population, develope industry, multiply wealth, and place public power on the immovable basis of population and wealth.

We may farther observe, that after the produce of the annual labour of every country has been reduced to its true value by its interchange with the produce of all countries, it has no longer any influence upon wealth, but with regard to its distribution and consumption. The national produce is distributed to the *land-owners* in the shape of *rents;* to the *capitalists* as *profits of stock;* and to all who participate directly or indirectly *in labour,* in the shape of *wages.* This distribution is more or less favourable to the progress of public and private wealth, according as stipulations in all private contracts are more or less free. All measures that alter the di-

rection of this distribution, and infringe upon its natural proportions, oppose more or less obstacles to wealth, and may even prove fatal to its existence. Independently of the distribution of the produce of labour to the land-owners, the capitalists, and the labourers, a part must be taken from this produce for government, and the servants of the state, which also has a considerable influence upon wealth. The consumption of the produce allotted to each individual, by the rents of land, the profits of stock, and the wages of labour, is subject to two laws: 1. The consumption of the annual produce must be inferior to the total quantity of that produce. A part should be saved for the increase of the capital stock; for unforeseen wants; and a progressive population. This economy acts as a safeguard against the blasts of fortune, and is a certain pledge of grandeur and prosperity: and so long as the consumption of public and private revenue does not absorb the whole produce of general labour, wealth is progressive, nations prosper, and are, in truth, advancing to the highest degree of power and splendour. 2. Consumption is more or less useful to the progress of wealth, according as it is or is not directed to solid and lasting enjoyments.

To conclude in the words of Mr. Ganilk: "In the economical system of modern nations, general labour is the spring of wealth, and general economy the only way of increasing the funds and the resources of labour; of developing its power, its faculties, and its genius; and of giving it a constant and unlimited progression. The general interchange of the produce of labour, by affording to the labouring classes new, varied, and inexhaustible enjoyments, stimulates their activity, excites their industry, encourages their efforts, and raises them to the highest degree of energy and industry, and the extent of a more or less beneficial consumption of the whole productions extends or narrows the bounds of wealth and opulence.

"Wealth, in the modern system of political economy, is the work of all men, of all nations, and, as it were, of the

whole human race; the reward of all individual efforts; and the end of private and general ambition. When all are rushing to the same end, the rights of all are respected, the interests of all attended to, and the conveniences of all consulted. All advance by the side of each, without elbowing, without injuring, without crushing each other. All are benefited by their reciprocal efforts, and all owe their successes to their general co-operation. To this admirable system, civilization is indebted for its progress; and when better understood, it will prove its most vigilant safeguard, and its firmest support."

Although we cannot treat upon half the subjects connected with political economy, yet we must not entirely pass over that of *population*, which is extremely interesting to individuals as well as states. The increase and diminution of the members of a country has always been thought an object deserving the attention of governments, though on this subject very different theories have been formed. Some ancient nations adopted regulations to prevent the increase of the number of their inhabitants; but in modern times it has been generally thought the part of wise policy to encourage population, as essential to the strength and prosperity of a state. Positive regulations against an increase of population are always nugatory, it being, most unquestionably, limited, in every country, by the means of subsistence; and if it ever pass this barrier, it must in a short time be restored to its proper level. So long as there is a facility of subsistence, the people will be encouraged to early marriages, and of course to the increase of the national stock of inhabitants. On this subject, Dr. Smith, in explaining the causes which proportion the reward of labour to the extent of the funds for its support, says, "It is in this manner that the demand for men, like that of any other commodity, necessarily regulates the production of men, quickens it when it goes on too slowly, and stops when it advances too fast. It is this demand which regulates and determines the state of population in all the different countries of the world—in North

America, in Europe, and in China; which renders it rapidly progressive in the first, slow and gradual in the second, altogether stationary in the last." A similar difference has been perceivable in the different states of Europe, at the same period of time, and in the same state, in different periods. As men cannot live without food, it will be readily admitted that these variations in the rate of population must have been universally preceded and accompanied by variations in the means of maintaining labourers, on which the demand must depend.

It is no less certain, that the actual increase of the funds for the maintenance of labour does not depend simply upon the physical capacity of a country to produce food and other necessaries, but upon the degree of industry, intelligence, and activity, with which these powers are at any particular period called forth. Thus we have seen or heard of countries possessing every requisite for producing the necessaries and conveniences of life in abundance, sunk in a state of ignorance and indolence from the vices of their governments, or the unfortunate constitution of their society; and continuing on for ages, with scarcely any increase in the means of subsistence, till some fortunate event introduces a better order of things; and then the industry of the nation being roused, and allowed to exert itself with more freedom, more ample funds for the maintenance of labour are immediately provided, and population is seen to make a sudden start forwards, at a rate wholly different from that at which it had before proceeded. An instance of this kind has been produced with regard to Russia, the population of which, though early inhabited, was so extremely low before the beginning of the last century, and has proceeded with such rapidity since the reigns of Peter the Great and Catharine II. It has also been noticed in the review of the history of nations, that the waste of people occasioned by the great plagues, famines, and other devastations, to which the human race has been occasionally subject, has been repaired in a much shorter time than it would have been, if the population, after

these devastations, had only proceeded at the same rate as before. From which circumstance it is obvious, that after the void thus occasioned, it must have increased much faster than usual; and the greater abundance of the funds for the maintenance of labour, which would be left to the survivors, indicates the usual conjunction of a rapid increase of the funds for its maintenance.

It is certain that the greater the number of persons any country contains, the greater are the means it possesses of carrying on agriculture, manufactures, and commerce; and likewise of defending itself against any hostile attempts of other states; a high degree of population has therefore been generally considered as conducive to national prosperity and security, and almost every modern writer on political economy has assumed an increasing population as one of the principal objects which the internal regulations of a country should be calculated to promote. Mr. Malthus, in his "Essay on the Principle of Population," has taken a different view of the subject. He has endeavoured to shew that population invariably increases where the means of subsistence increase, unless prevented by some very powerful and obvious checks. He goes farther, and lays it down almost as an axiom, that there is a constant tendency in all animated life to increase beyond the nourishment prepared for it, and he traces to this source a very considerable portion of the vice and misery, and of that unequal distribution of the bounties of nature, which it has been the object of the philanthropist in all ages to correct. To place the subject in a different point of view, we may endeavour to ascertain what would be the natural increase of population, if left to itself with perfect freedom, and what might be expected to be the rate of increase in the productions of the earth under the most favourable circumstances of human industry. In some of the northern states of America, in which the means of subsistence have been more ample, and the checks to early marriages fewer, than in any of the modern states of Europe, the popu-

lation has been found to double itself for several successive periods every twenty-five years. In the back settlements this was effected in fifteen years. Sir William Petty supposed it possible that population might be doubled in ten years. Mr. Malthus takes the slowest of these rates of increase, and assumes, that population, when unchecked, goes on doubling itself every twenty-five years, or that it increases in a *geometrical* ratio. The rate according to which the productions of the earth may be supposed to increase, is not so easily determined; but when acre has been added to acre, till all the fertile land is occupied, the yearly increase of food must depend upon the melioration of the land already in cultivation; and Mr. Malthus shews, that, on this supposition, the means of subsistence, under circumstances the most favourable to human industry, could not possibly be made to increase faster than in an *arithmetical* ratio. He then points out the necessary effects of these two different rates of increase, and observes, that taking the whole earth, by which means emigration is put out of the question, and supposing the present population equal to a thousand millions, the human species would increase as the numbers 1, 2, 4, 8, 16, 32, 64, 128, 256, and subsistence as 1, 2, 3, 4, 5, 6, 7, 8, 9. Hence, in two centuries, the population would be to the means of subsistence as 256 to 9; in three centuries, as 4096 to 13; and in two thousand years the difference would be almost incalculable. Upon this supposition, no limits whatever are placed to the produce of the earth; it may increase for ever, and be greater than any assignable quantity; but the power of population being in every period so much superior, the increase of the human species can only be kept down to the level of the means of subsistence, by the constant operation of some powerful check.

From what has been said, it appears, 1. That man, like all other animals, multiplies in proportion to the means of subsistence which are placed within his reach.

2. That there is a power of increase in the human race, much greater than is generally exercised, always ready to exert itself as soon as it finds an opening, and appearing continually in sudden starts of population, whenever the funds for the maintenance of labour have experienced an increase, in whatever way this may have been occasioned.
3. That this power of increase is so great, and, in its nature, necessarily so different from any increase which can result from adding together different portions of a limited quantity of land, or gradually improving the cultivation of the whole, that the funds for the maintenance of labour cannot, under any system, the most favourable to human industry, be made permanently to keep pace with such an increase of population as has been observed to take place for short periods in particular countries; and consequently, as man cannot live without food, that the superior power of population cannot be kept on a level with the funds which are to support it, without the almost constant operation of considerable checks of one kind or other. These checks, according to Mr. Malthus, are all resolved into moral restraint, vice, and misery, which may be divided into two general classes, *viz.* those which operate in *preventing the birth* of a population that cannot be supported, and those which *destroy it* after it has been brought into existence; or, as they are denominated by Mr. Malthus, the *preventive* checks, and the *positive* checks. The determination to defer or decline matrimony from a consideration of the inconveniences to which a large portion of the community would subject themselves by pursuing the dictates of nature, Mr. Malthus denominates the *preventive* check: and whatever contributes to shorten the natural duration of human life; as extreme poverty, bad nursing of children, excesses of all kinds, the whole train of common diseases and epidemics, wars, pestilence, plague, and famine are the *positive* checks to population.

The necessary and constant effect of some checks to population being fully established, and these checks being divisible into the classes above mentioned, we cannot for a moment hesitate in determining which of them we should wish to see put in operation; and it follows, that in order to improve the condition of the lower classes of society, to make them suffer less under any diminution of the funds for the recompence of labour, and enjoy more under any actual state of these funds, every attempt should be made to discourage helpless and improvident habits, and to raise them as much as possible to a sense of the dignity of their nature. The causes which chiefly tend to foster helpless, indolent, and improvident habits among the lower classes, are despotism and ignorance, and whatever increases their dependence, and weakens the motives to personal exertion. Whereas the causes which principally tend to promote habits of industry and prudence, are good government and good education, and whatever has a tendency to increase their independence and respectability. Wherever the registers of a country indicate great mortality, and the general prevalence of the check arising from disease and death, over the check arising from prudential habits, there we find the people debased by oppression, and sunk in ignorance and indolence. On the other hand, wherever the registers of a country indicate a small mortality, and the prevalence of the check from prudential habits above that from premature mortality; there we as constantly find security of property established: some degree of intelligence and knowledge, with a certain taste for cleanliness and comforts.

Mr. Malthus thinks the effect of our poor laws, is to encourage marriage between persons who have no prospect of providing for the presumptive issue of marriage. Thus, he adds, these laws create mouths, but are perfectly incompetent to provide food for them; instead of raising the real price of labour, by increasing the demand for labourers, they tend to overstock the market, to reduce the demand, and diminish the value. They raise the price of provisions by increasing

the consumption, and by supplying the parochial pensioners with the means of obtaining them. He shews, that in a moral point of view the effects of the poor laws are equally injurious to the best interests of society: he is not, however, an advocate for their immediate and abrupt abolition: he suggests what will answer the end, *viz.* a gradual abolition of them, by proposing that no child born from any marriage taking place after the expiration of a year from the date of the law, and no illegitimate child born two years from the same date, should be entitled to parish assistance. This, he thinks, would operate as a fair notice, which no man could mistake; and without pressing hard upon any individual, would at once throw off the rising generation from that wretched dependence upon the government and the wealthy, the evil consequences of which are almost incalculable.

Although the good intentions of Mr. Malthus are clearly evident in every page of his work, we are not prepared to follow him in all his theories; in endeavouring to avoid one extreme, he has probably fallen into its opposite. The system of Providence, with respect to the increase of the population does not seem to us liable to such objections as must present themselves to every reflecting person, on the careful perusal of the Essay on Population. Besides, admitting that the parish funds were shut up from the poor, and the public benevolence were restrained by a fixed and undeviating law; no act of the legislature could blunt the feelings of individuals—private benevolence would undoubtedly be extended in proportion as public charity was withdrawn.

Mr. Malthus lays it down as a fundamental maxim, that in any efforts which we may make to improve the condition of the lower classes of society, we must not, on any account, do any thing which tends directly to encourage marriage. He adds, that "the precise reason why I think that more children ought not to be born than the country can support, is, that the greatest possible number of those that are born may be supported. We cannot, in the nature of things, assist the

poor, in any way, without enabling them to rear up to manhood a greater number of their children. But this is of all other things the most desirable, both with regard to individuals and the public. Every loss of a child from the consequences of poverty, must evidently be preceded and accompanied by great misery to individuals; and with respect to the public, every child that dies under ten years of age, is a loss to the nation of all that has been expended in its subsistence till that period. Consequently, in every point of view, a decrease of mortality, at all ages, is what we ought to aim at. We cannot, however, effect this object, without first crowding the population, in some degree, by making more children grow up to manhood; but we shall do no harm, in this respect, if, at the same time, we can impress these children with the idea that to possess the same advantages as their parents, they must defer marriage till they have a fair prospect of being able to maintain a family. If we cannot do this, all our former efforts will have been thrown away. It is not in the nature of things, that any permanent and general improvement in the condition of the poor can be effected without an increase in the preventive check; and unless that take place, either with or without our efforts, every thing that is done for the poor must be temporary and partial; a diminution of mortality, at present, will be balanced by an increase of mortality in future; and the improvement of their condition in one place, will proportionally depress it in another. This is a truth so important, and so little understood, that it can scarcely be too often insisted upon."

The progress of the population of the world, and its present total amount, cannot be ascertained with much precision, as there are no sufficient grounds on which such a computation can be formed. Sir W. Petty, in 1682, stated the population of the world at only 320 millions. Other writers have estimated it much higher; some, indeed, have gone so far as to suppose there were at least 1000 millions of inhabitants on the earth: and the late Mr. J. J. Grellier says, a

strong presumption that the inhabitants of the earth at present (1801) exceed considerably a thousand millions, arises from the circumstance, that, in almost every country where the people have been numbered, or sufficient data obtained for computing their number, it has been found considerably greater than it had been previously supposed. In Great Britain, for instance, the most correct estimates previously to 1801, did not make the population exceed seven or eight millions; whereas, by the enumeration in that year, it appeared to amount to nearly eleven millions; and, as will be seen hereafter, in 1811, to more than twelve millions and a half. The population of France was estimated by M. Susmilch at sixteen millions, others supposed it to be eighteen, twenty, and twenty-four millions; but at the commencement of the revolution in 1789, it appeared, from the returns of the births and burials, to contain thirty millions of inhabitants.

The following table, containing the number of inhabitants in each European country, and also the population of its chief cities, will, though it be only an approximation to the truth, afford a comparative view of the present population of the European states, and of their respective capitals.

Countries.	Population.	Capitals.	Population.
British Dominions, including Ireland - -	15,396,650	London - - - -	1,050,000
Denmark and Norway -	2,750,000	Copenhagen - - - -	90,000
Sweden - - - - - -	2,000,000	Stockholm - - - -	75,000
Russia - - - - - -	36,000,000	St. Petersburgh - - -	180,000
Austria - - - - - -	20,000,000	Vienna - - - - -	224,550
Prussia - - - - - -	5,200,000	Berlin - - - - -	150,000
Germany - - - - -	24,000,000	Frankfort on the Mayne	40,000
Holland - - - - - -	2,220,000	Amsterdam - - - -	212,000
France, including the Netherlands - - -	36,345,000	Paris - - - - - -	547,756
Spain - - - - - - -	10,351,000	Madrid - - - - -	147,540
Portugal - - - - -	2,550,000	Lisbon - - - - -	200,000
Switzerland - - - - -	1,800,000	Berne - - - - - -	13,000
Italy - - - - - - -	12,000,000	Rome - - - - - -	180,000
Turkey - - - - - -	8,500,000	Constantinople - - -	400,000
Total	179,112,650	Total	3,509,816

The population of Great Britain was very long a subject of great uncertainty, both with respect to the actual number of inhabitants, and their increase or diminution; it became the subject of frequent controversy among writers on the internal policy and strength of the country, till it was at length, in a measure, set at rest by an act of parliament, passed on the 31st of December, 1800, which directed a general enumeration of houses and families, and persons, to be made on the tenth of the following March, and in Scotland, on account of the coldness of the climate, as soon as possible after that day. The result was, that Great Britain contained a population of nearly eleven millions.

The islands of Guernsey, Jersey, Alderney, and Sark; the Scilly islands, and the Isle of Man, were not included in this enumeration: the total population of these islands has been usually reckoned at about 80,000. The number of houses in Ireland has been nearly ascertained by the collection of a hearth money tax, from whence it has been computed, that the population of that island exceeds four millions of persons; therefore, with a moderate allowance for those places from which no returns were received, and for some omissions in others, the total population of the united kingdom of Great Britain and Ireland, amounted, in 1801, to more than fifteen millions. At the commencement of the preceding century, Dr Davenant published an account of the number of houses in England and Wales, taken in the year 1690, and a comparison of them shews an increase from 1690 to 1801 of 261,708 houses, which makes an increase of the population equal to nearly a million and a half of people. There must, however, have been a greater increase than this, as the number of soldiers and seamen in 1801, certainly exceeded by much those employed in 1690. The circumstance that caused considerable disagreement in the estimates, which, previously to the enumeration, had been formed on this subject, was the want of sufficient accounts to determine the proportion of persons to a house. Dr. Davenant and Dr. Brakenbridge

reckoned six persons to a house, whereas Mr. G. King allowed but little more than $4\frac{1}{2}$ in London. and $4\frac{3}{10}$ in the other cities and market towns, and four in the villages. Dr. Price asserted, that six persons to a house for London, and five to a house for all England, was no doubt too large an allowance; but it was found, in 1801, that in England and Wales the proportion was $5\frac{3}{5}$ persons to a house, and in Scotland $5\frac{2}{5}$. The proportion of inhabitants to a house differs very considerably in some counties of England; the principal cause of this difference is the large towns, and particularly the seaports which some of them contain; as in such places the inhabitants live more crowded together than in moderately sized inland towns.

TABLE of the Population of Great Britain, according to the Returns made to Parliament in 1811, compared with the Population in the Years 1700, 1750, and 1801.

	Population.				Area in Square Miles.
	In 1700.	In 1750.	In 1801.	In 1811.	
England - -	5,108,500	6,017,700	8,609,000	9,855,400	50,210
Wales - - -	366,500	449,300	559,000	632,600	8,125
Scotland - -	1,048,000	1,403,000	1,652,100	1,865,000	29,167
Totals -	6,523,000	7,870,000	10,820,100	12,353,000	87,502

Population, taking the Army and Navy separately in 1811.

England	Males - -	4,575,763	Males in England - -	4,575,763
	Females -	4,963,064	Wales - - -	291,633
Wales	Males -	291,633	Scotland - -	826,191
	Females	320,155	Army and Navy, &c. - - -	640,500
Scotland	Males - -	826,191		
	Females -	979,497	Total - -	6,334,087
Army, Navy, Marines, and Seamen, in registered vessels	- -	640,500	Females in England -	4,963,064
			Wales - -	320,155
			Scotland -	979,497
Grand total - - - -		12,596,803	Total	6,262,716

	Houses.		Occupations.		
	Inhabited.	By how many Families occupied.	Families chiefly employed in Agriculture.	Do. chiefly employed in Trade, Manufactures, and Handicrafts.	Do. not comprehended in the two preceding Classes.
England -	1,678,106	2,012,391	697,353	923,588	391,450
Wales - -	119,398	129,756	72,816	36,044	20,866
Scotland -	304,093	402,068	125,799	169,417	106,852
Totals - -	2,101,597	2,544,215	895,998	1,129,049	519,168

Families in	England - - - -	2,012,391
	Scotland - - - -	402,068
	Wales - - - -	129,756
	Total	2,544,215

This gives us rather more than $4\frac{1}{2}$ persons to each family.

We might advance step by step in this subject to a very great length, did not the limits assigned to our work prevent it; we might shew in what way arithmetical calculations may be applied to political uses and subjects, particularly to those to which we have already referred, as the public revenues—the population of countries, and of the known world—the extent and value of the lands of a nation—taxes, trade, &c. We might shew by what method, from the bills of mortality in different places, tables have been constructed, from which it is ascertained how many persons, upon the average, out of a certain number born, are left at the end of each year to the extremity of life: and how, from these tables, which are founded on the doctrine of Chances, explained in the first volume, p. 548-51 the probability of the continuance, or duration of life is to be estimated. Hence is derived what is called the Expectation of Life, on which is founded the doctrine of Annuities and Reversions, so important in every

state arrived to a certain pitch of civilization, and the whole system of facts relating to the population of any country. Such kind of calculations are frequently made with a view to ascertain the comparative strength and prosperity of any two or more nations, that is, in fact, their wealth. Political arithmetic, for such it may be denominated, does not determine in what national wealth consists; but it enables us to estimate the value of whatever passes by that name, and distinguishes the proportions by which the component articles may be applied to purposes conducive to the safety and prosperity of any community. It cannot be denied, that in the application of arithmetic to topics of political economy, it loses much of its precision, from the fluctuating nature of all kinds of property, both with respect to distribution and value: it retains however a sufficient degree of certainty to become an interesting object to every person who wishes to acquire a just idea of the resources either of the community to which he belongs, or of other nations. On this subject, if the particulars assumed as facts, were quite correct, the deductions obtained from them would be as determinate and invariable as in any other branch of arithmetic; but as the former can never be depended upon, the latter will necessarily only be approximations to the truth. Such approximations however may be sufficient for most purposes of practical utility.

To the student, who would make Political Economy the subject of his researches, we can recommend nothing better than Smith's "Wealth of Nations," to which in many respects the foregoing article may be considered as an introduction. If Dr Smith's work be thought too long, there is a very full abridgment of it, entitled "An Analysis of the Wealth of Nations," in a thin octavo. Mr. Boileu, has also published an "Introduction to the Study of Political Economy," which he intends chiefly as an elementary work, preparatory to the Study of the "Standard Treatise of Adam Smith." The "Wealth of Nations" should, indeed, engage a large portion of every young man's attention who may hereafter be called to

take a share in the public concerns of his country. Having carefully studied Dr. Smith's work, let him peruse with care "An Enquiry into the various Systems of Political Economy; their Advantages and Disadvantages; and the Theory most favourable to the Increase of National Wealth. By Charles Ganilk" This very valuable work contains a great number of extremely interesting discussions, as well as a very fair and candid statement of the different systems, as maintained by all the principal authors on the subject: to whose several works, M. Ganilk refers with an accuracy and precision which cannot fail to be highly useful to those who would enter largely into this study. To these should be added the "Essay on Population," by Mr. Malthus, and the several works to which it gave rise: and it may be added, that in some of the early volumes of the Edinburgh Review, the several parts of Political Economy are discussed with great talent and discrimination. See particularly vol. i. iv. vi. xi. &c.

CHAP. XXVI.

OF MAN, HIS STRUCTURE AND FUNCTIONS.

General view of the human frame. Of the bones—Marrow—Cartilage—Synovia. Of the skeleton—The Head—Face; teeth, and bone in the tongue.—The Trunk—Spine; pelvis, and thorax or chest; ribs, sternum. Superior Extremities—Shoulder; arm and hand. Inferior Extremities—Femur—Leg; patella, and foot. The muscles. Muscular motion. The brain and nerves.

In contemplating the human structure—in developing its various functions—no attentive person can avoid beholding in a most striking manner, the wisdom and goodness of the Creator; to which, in fact all knowledge and every system of education should lead.

From the superiority of his organization, Man, when compared with all other animated beings, may justly place himself at the head of the visible creation. His form is erect, his power is pre-eminent, and capable of bringing under his control the powers and perfections of all other creatures: his passions, given for the wisest purposes, are within the range of his own discipline; his happiness not confined to things of sense; his knowledge is progressive, and his duration is eternal. To his rank and station in the present world, this and the following

chapter will be devoted; to his high expectations for futurity, the concluding pages of the work will be appropriated.

To understand the necessity and advantages of such a structure as that belonging to the human frame, we must consider what Man is, and what are the faculties with which he should be endowed. We must remember that the thinking part, or mind, is to be placed in a corporeal fabric, to hold a correspondence with other material beings by the intervention of a body; hence the necessity of the brain, in which the mind, or thinking principle, dwells, as governor and superintendent of the whole fabric. As the mind is to correspond with the material beings which surround her, of course she must be supplied with organs fitted to receive the different kinds of impressions that they will make. Hence she is provided with the organs of sense: the eye is adapted to receive impressions from light; the ear to receive those arising from sound; the nose is adapted to smelling, the mouth to tasting, and the skin to touching.

Again, the mind must be provided with organs of communication with the several parts of her own body, by means of the brain, fitted to convey her commands, and to have an influence over the whole. Hence nerves are given, which are a sort of cords that rise in the brain, and are dispersed in branches to every part of the body. They are intended to be the occasional monitors against all such impressions as might endanger the well being of the whole frame, or any particular part of it; which vindicates the Creator, in having subjected us to those disagreeable and painful sensations to which we are exposed in a thousand accidents of life.

The mind must likewise be endued with the power of moving its habitation, the corporeal frame, from place to place; and accordingly she is furnished with limbs, and with muscles and tendons, which are the instruments of motion, and which by some unknown power, she has completely under her control.

To give stability, support, and shape to this fabric: to keep

the softer parts in their proper places, and for other important purposes, there must be some firm prop-work. Such is the bony skeleton, withwhich we shall begin our description.

Of the Bones. The bones, constituting the basis and support of the body, are its most hard and solid parts: they are however organized like the other parts of the body, and like them supplied with blood by numerous vessels adapted to the purpose. Before birth, *cartilage*, a substance that will be explained hereafter, supplies the place of bones. And this cartilage is not afterwards hardened into bone, but is actually absorbed and carried away by one set of vessels, while another set is employed in depositing, in its room, matter for the formation of bone.

The bones are composed of a vascular substance, not differing materially in structure from the rest of the body, except that there is deposited in the interstices an earthy matter, which gives to the whole mass rigidity, strength, and a permanent figure.

According to the differences in their forms, bones are divided into the *long* and *flat*: and two kinds of structure may be observed in them: in the one, the bony substance is condensed, and without interstices; in the other, there is a mere net-work of bony fibres and plates, leaving numerous intervals. This latter is denominated the *cancellous* substance of bones.

The cylindrical part of long bones is composed of the firmer substance; but the centre all the way through is left hollow, to contain a substance called marrow. In those extremities of bones which form the joints, to increase their surface there is a thin layer of the compact substance, but all the interior is cancellous. In broad flat bones, the firmer substance is formed into two plates or tables, and the interval between these is occupied by cancelli.

Many advantages arise from this arrangement. The long bones are made slender in the middle, to allow of the con-

venient collocation of the large muscles around them: they become expanded at their extremities, to afford an extent of surface for the formation of joints, and the support of the body. The bones are hollow, for if all the earthy matter had been compacted in the smallest space by bringing its parts close together, they would have been such slender stems, as to be unsuitable to their offices; and if they had been of their present dimensions, and solid throughout, they would have been too weighty and unwieldy. The bones possess nerves as well as arteries, veins, and absorbents; and though in their natural and healthy state they seem to be insensible, they become exquisitely sensible and painful when diseased.

Bones are covered by a strong and firm membrane, termed *periosteum*, on which the vessels are first distributed, and thence descend into the substance of the bones.

The *Marrow* is an oily substance, secreted, or separated from the blood: its precise use is not yet ascertained, but it is known that the destruction of the marrow produces the death of the bone.

Bones are connected with each other by *Ligaments*, which are strong, white, flexible substances, and but little elastic: there are two kinds of ligaments, the round, or cord-like, which grow from the head of one bone, and are inserted into that of another, tying the bones together; and the capsular ligaments, which inclose the whole joint, as in a purse or bag, and which have numerous arteries opening upon their internal surface, for the purpose of keeping them moist, and of diminishing friction.

Cartilage is a semi-pellucid substance, which enters into the composition of several parts of the body: to preclude friction and concussion; all the bones, forming moveable joints, have their ends covered with plates of this cartilage; which being of a solid, smooth, elastic nature, renders the joints easy, and free from shocks in running, jumping, &c.

Synovia. Besides the fluid which the capsular ligament throws out, there are small fringe-like bodies placed within the

joints, for securing a constant supply of moisture. They secrete or separate a glairy and slippery liquor, called synovia, intended for lubricating the different surfaces of the joint. After the synovia has done its office, it is taken up into the mass of blood by the absorbent vessels, which arise by open extremities from all the cavities of the body.

Of the Skeleton. The bones of an animal connected together after the soft parts are removed, is called a skeleton. The human skeleton is divided, for the purpose of description, into the head, the trunk, and the extremities. *See the plate.*

By the Head is meant all that spheroidal part which is placed above the first bone of the neck; it therefore comprehends the bones of the skull, and those of the face. The *skull* consists of eight bones, which form a vaulted cavity for lodging and defending the brain. These bones are composed of two plates or tables, and intermediate cancelli or lattice-work, nearly of the same structure and use, as that of other bones. The outer plate is the thicker and stronger of the two, for the purpose of warding off external injuries from the head. The bones of the skull are joined together by sutures, which are indented or dove-tailed seams. The bones of the skull ossify from the centre towards the circumference, their fibres spreading and extending on every side; till at length the different bones meet, and shooting in between each other, form the suture or serrated line. In this way Nature, in the formation of all the bones, hastens their ossification, by beginning the process in many points at once; and she observes the same law in healing or uniting a broken bone, as well as in forming the skull.

The *face* is the irregular pile of bones composing the fore and under part of the head. It constitutes the bony portion of some of the organs of sense; affording sockets for the eyes, an arch to the nose, and a support to the palate: it forms the basis of human physiognomy. It is usually divided into the upper and lower jaws: the *former* consists of six bones on each side, and of one in the middle, and of sixteen teeth.

The *latter* consists of only one moveable bone and sixteen teeth. The fore part of this bone is termed the chin.

The *teeth*, as we have observed, are generally in number sixteen above, and as many below, though some people have more, and some less. The part appearing without the socket is called the base or body; and those parts within, the roots or fangs, which become smaller towards the end farthest from the base. Each tooth is composed of its enamel and internal bony substance: the enamel has no cavity or place for marrow, and is so extremely hard, that saws and the hardest files can with difficulty make an impression upon it. It is thickest upon the base, and becomes thinner towards the extremities of the roots. The internal bony part of the teeth is of the nature of other bones; like them it is supplied with blood-vessels and nerves: it is subject likewise to the disorders of other vascular parts: hence, when by any accident or disease, the enamel breaks or falls off, and the internal part becomes exposed to the air, it soon corrupts; and a carious tooth is produced, hollow within, though perhaps having only a very small hole externally.

The vessels and nerves enter by a very small opening, placed a little to the side of each root, and thence descend, to be loged in canals, formed in the middle of the teeth; here they are employed in replacing thewaste constantly made by the attrition which they undergo in mastication.

The teeth are commonly divided into three classes, viz. the *incisores*, or cutting teeth; the *canini*, or eye teeth; and the *molares*, or grinders. There are four incisores, or cutting-teeth, in the fore part of each jaw, and they take their name from their use in cutting the food: the canini, so called from their resemblance to the tusks of dogs, are two in each jaw, and are placed one on each side the incisores. The grinders, of which there are ten in each jaw, are so named, because, from their shape and size, they are admirably fitted for grinding the food. Each of the incisores and canini is furnished only with a single fang, but in the molares of the under jaw, there

are two, and in those of the upper jaw there are three fangs.

This structure and arrangement of the teeth, it has been observed by anatomists, display great wisdom. In comparing the subject with the principles of mechanics, Chap. I. Vol. II. we find that the under jaw acts as a lever, having its fulcra, or fixed points, at its articulations with the skull; that this lever is worked by its muscles, and that the food constitutes the object of resistance. Now it is evident that the grinders, as well from being placed nearest the centre of motion, as from the unevenness of their surfaces, are calculated to act the parts given them to perform; while the others, being placed farther from this point, and also from the sharpness of their edges, and those overlapping each other as the blades of scissors do, are particularly adapted to cut and tear the food.

The pain called tooth-ach arises from a nerve, which, with a vessel, resides in a hollow, formed, for protection, in the centre of the tooth; this nerve, by the decay of the tooth, being exposed to the cold, excites the pain referred to.

Each person has two sets of teeth, the first, about twenty in number, and small in size, fall out at a certain age, to make room for larger ones The former are called deciduous, or temporary; the latter, intended to last through life, are denominated permanent.

There is a small but very important bone in the *tongue*, nearly of the figure of the lower jaw-bone; and which lies immediately between the root of the tongue, and the upper part of the wind-pipe; it carries upon it a valvular cartilage, for shutting the passage, and preventing any thing getting down this tube: while its branches extend along the sides of the throat, keeping the openings of the wind-pipe and gullet extended, as one would keep a bag extended by two fingers. This bone is the centre of motion of the tongue; for in it the muscles, which compose the bulk of the tongue, are inserted: —of the motions of the wind-pipe; for it forms at once the top of the wind-pipe, and the root of the tongue, and joins

them together:—of the motions of the gullet; for the branches surround the upper part of that tube, and join it to the wind-pipe: and it also forms the centre for all the motions of the throat in general; since muscles come down from the chin to this bone, to move the whole throat upwards, others ascend from the breast, to move it downwards; while different muscles come from the sides, to move the throat backwards.

The Trunk of the Body comprises the spine, the pelvis, and the thorax, or chest. The *Spine*, or back-bone, is a chain of joints of very wonderful construction: it extends from the skull to the end of the loins, and consists of twenty-four distinct bones, named *vertebræ*, so called from the Latin word *vertere*, because they are admirably formed for turning every way. They also form a tube or canal along the whole length of the spine, for lodging and defending the spinal marrow; and they support the whole weight of the trunk, head, and arms, without suffering under the longest fatigue, or the greatest load which the limbs can bear. Here we observe, that nature has established the most opposite and inconsistent functions in one set of bones; for their motions are so free, as to be turning continually, yet so strong, as to support the whole weight of the body, and so flexible, as to turn in all manner of directions; yet so steady within, as to contain and defend the most material and most delicate part of the nervous system.

The vertebræ are divided into those of the neck, the back, and the loins. In the neck there are seven, in the back twelve, and in the loins five.

Of the Pelvis. The pelvis is a circle of large and firm bones, standing as an arch between the lower extremities and the trunk: this arch is wide and strong, to give a firm bearing to the body: the several bones of which it is composed are large, to afford a deep socket for the implantation of the thigh bone: its motions are free, bearing the trunk above, and rolling upon the thigh bones below; and it is so com-

pletely the centre of all the great motions of the body, that when we believe the motion to be in the higher parts of the spine, it is actually either the last vertebræ of the loins bending upon the top of the pelvis, or the pelvis itself rolling upon the heads of the thigh bones.

The pelvis, so named from its basin-like form, is constructed of four large bones, viz. 1. The *os sacrum*, behind, on which the spine rests, is of an irregular triangular shape, broad above for supporting the trunk, and narrow below; on the outside it is convex, and in the inside concave. Within is a triangular cavity, which is a continuation of the canal of the spine: here the spinal marrow ends, and branching into a great number of thread-like nerves, has the form of a horse's tail. These nerves afterwards go out by five great holes, which are on the fore-part of the bone, to be distributed to various parts. 2. The *os coccygis* is a continuation of, or appendage to the *sacrum*; and it consists of four small bones, each of which becomes smaller, as it descends, till the last ends in a point; and by bending inwards, it serves to contract the lower opening of the pelvis, so as to support effectually the viscera within. 3. The sides and forepart of the pelvis are composed of *two* bones, which correspond in size and figure, and being of a most irregular shape, they are called *ossa innominata*, or bones without a name. In children, each of these bones consists of three pieces; but which, as the ossification becomes more perfect, are so firmly united, as to form but one. The pelvis is the base for supporting the superior parts of the body: it is moreover so constructed as to receive into its sockets the thigh-bones, by which means it connects the lower extremities with the upper parts of the frame; and, lastly, by forming a kind of basin at the lower end of the trunk of the body, it aids in sustaining the viscera, while its outside surfaces serve as convenient places for the origin and insertion of numerous muscles, which perform, with mechanical advantage, some of the motions of the trunk, and many of those of the lower limbs.

The *thorax*, or chest, is that large cavity, reaching from the neck to the lower end of the breast-bone, and still lower downwards, at the back. It is intended to afford a secure and commodious residence for the heart, lungs, &c. and is formed by the twelve dorsal vertebræ, the ribs and the sternum.

The *ribs* are long, curved, flattened, and narrow bones, attached behind to the dorsal vertebræ, and joined in front to a piece of cartilage: they not only defend the heart and lungs, but also assist in breathing, being joined to the spine by regular hinges, which allow of short motions: these yield to the motion of the ribs, and return again, from their elastic nature, when the muscles cease to act. Of the twelve ribs, seven have their cartilages inserted into the breast-bone, and are called true ribs: but the other five, whose cartilages do not reach that bone, but run into each other, are named false ribs.

The *sternum*, or breast-bone, is commonly composed of two pieces of bone, and a cartilage united, to which the ends of the ribs and collar-bones are articulated, and by means of which the cavity of the chest is completed.

Of the Superior Extremities. Each superior extremity consists of the shoulder, arm, fore-arm, and hand. The *shoulder* includes two bones, the clavicle and scapula. The *clavicle*, or collar-bone, is placed at the root of the neck, and at the upper part of the breast: it serves for the shoulder, as a kind of arch, supporting and preventing it from falling in and forwards upon the breast. The collar-bones also make the hands strong antagonists to each other, without which they could not have been so. The *scapula*, or shoulder-blade, is broad and flat, placed upon the outside of the ribs, and serving as a base to the whole superior limb. It is not in immediate contact with the ribs, but is separated from them by several layers of muscular flesh; so that this bone may glide upon the trunk, and increase the motion of the

limb which is suspended from it. Accordingly, it serves as a moveable intermediate base to the whole arm. For this purpose it is fastened to the trunk by numerous strong muscles, by means of which it may be moved in almost all manner of directions.

The *arm* is usually divided, in the description, into two parts, which are articulated with each other at the elbow: the upper part, extending from the shoulder to the elbow, retains the name of arm, and the lower part is called the fore-arm.

The *arm*, or humerus, is a single bone, long and cylindrical, joined by a round head to the scapula above, and articulated with the bones of the fore-arm at the elbow, serving as a base on which they perform their various movements.

The fore-arm is composed of two bones, named the *ulna* and the *radius*. The ulna extends from the wrist on the side of the little finger to the point of the elbow, where it assumes a hook-like form; the concave side of which being fitted to the lower end of the arm-bone, produces the motions of flexion and extension, so that the fore-arm may be bent to a very acute angle, or extended into almost a straight line with the arm. The radius has its position reversed with that of the ulna; for the latter has its greater end upwards, but the greater end of the radius is downwards. While the ulna only bends the arm, the radius carries the wrist with a rotatory motion. The radius is hollowed at its lower end for receiving the bones of the wrist, but the ulna does not reach quite so far as to come in contact with those bones.

The *hand* is divided into the carpus, or wrist, the metacarpus, and the fingers and thumb. The *carpus* contains eight bones, disposed in rows, which allow motion on all sides; and by a quick succession of these motions, the hand may be moved in a circle. The *metacarpus* has five bones, and each of the fingers three, the thumb only two.

Of the Inferior Extremities. Each of the lower

extremities comprises the thigh, the leg, and the foot, and has a great analogy in the structure and distribution of its parts with the upper extremities.

The *femur*, or thigh-bone, is the largest of the cylindrical bones in the body. It has a round head, contained in a socket of the *os innominatum*. This bone not only serves as a fixed point for performing several motions of the trunk, which it maintains like a pillar; but it also affords a base for the leg to carry on its own motions, and is principally concerned in walking, running, &c.

The *leg* is composed of three bones, two long ones, called the tibia and fibula, and a small one placed at the knee. The *tibia*, so named from its resemblance to a musical pipe, is a long triangular bone at the inside of the leg; which runs nearly in a straight line from the thigh-bone to the ancles, supporting the whole weight of the body; and has its upper part expanded into a large surface for receiving the lower end of the thigh-bone, and forming the knee-joint. This articulation admits flexion and extension, and is secured by very strong ligaments. The lower end of the tibia is articulated with the foot, and forms the inner ancle.

The *fibula* is a long slender bone, placed at the outside of the tibia, and its head is connected to that bone by ligaments, but does not reach high enough to enter into the composition of the knee-joint. It descends to the foot, where it forms the external ancle; and is connected with the tibia along its whole length, by a broad, thin ligament, similar to one that is between the bones of the fore-arm.

The patella, or *knee-pan*, is a small thick bone, of an oval, or rather triangular form. The base of this triangular bone is turned upwards to receive the tendons of the great muscles, by means of which the leg is extended; the apex is turned downwards, and is tied by a very strong ligament to the upper part of the tibia, just under the knee. The knee-pan acts as a lever, and enables the muscles of the leg, to become more powerful in extending the limb. To facilitate its mo-

tions, its external surface is smooth, covered with cartilage, and fitted to a kind of pulley of the thigh-bone, upon which it moves.

The *foot* is composed of the tarsus, metatarsus and toes. The *tarsus* has seven bones: the *metatarsus*, five; and the bones of each toe are three, except the great toe, which has only two.

Of the Muscles. The organs which move the bones, and put the whole frame in motion, are called muscles; they, in fact, constitute all that part of the human body known by the name of flesh: they consist of bundles of red fibres, but the colour is not essential, it can be removed by repeated washings and maceration. Each large muscle consists of two distinct portions, namely, its belly, which is the only part that is active, and the shining extremities, or *tendons*: these last are used to fix the muscles to the moveable parts, in consequence of which, a greater power is brought to act upon them in the same way as manual labour is often assisted by ropes, in moving weighty bodies. The tendons are accordingly employed in implanting muscles upon bones, and are not discoverable in the heart, stomach, &c. Muscles are universally the organs of motion in animals: they are of different sizes and shapes, according to the degree of force required of them, and the form of that part on which they are situated: those on the body or trunk, are mostly broad and flat; but those on the extremities, are of a long, round figure, with tendinous ends.

Each muscle performs its action by contracting both ends towards the centre: when one of these ends is fixed to a point as a fulcrum, the other, with the bone united to it, is necessarily drawn towards it; and thus, by the co-operation of several muscles, the movement of the limb, and even of the whole body, is effected. As soon as the motion is over, the muscles, which performed it, relax, and allow their ends to elongate to their former position. There is always an exact relation between the joint, and the muscles that move it.

Whatever kind of motion the joint, by its mechanical construction, is capable of performing; that motion, the annexed muscles, by their position, are capable of producing. For example, if there be, as at the knee and elbow, a hinge joint, capable of motion only in the same plane, the muscles and tendons are placed in directions parallel to the bone, so as by their construction to produce that motion, and no other. Whereas, at the shoulder and hip, where, what is called the ball and socket joint allows, by its construction, a rotatory or sweeping motion, tendons are placed in such a position, and pull in such directions, as to produce all the motions of which the joint admits. In the head and hand there is a specific mechanism in the bones for rotatory motion, and there is accordingly in the oblique direction of the muscles belonging to them, a specific provision for putting this mechanism of the bones into action. The oblique muscles would have been useless without that particular articulation: and the articulation would have been useless without the muscles.

As we have seen that the muscles only act by contraction, the reciprocal energetic motion of the limbs, or their motion with a proper degree of force, in opposite directions, can only be produced by the instrumentality of opposite or *antagonist* muscles answering each other. For instance, the muscles placed in the front of the arm, by their contraction bend the elbow, and with such a degree of force as the case requires, or the strength admits of. The relaxation of these muscles after the effort, would merely let the fore-arm drop down: for the back stroke, therefore, and that the arm may not only bend at the elbow, but also extend and straighten itself with force, other muscles are placed on the hinder part of the arm, to bring back the fore-arm into a straight line with the humerus, with a force equal to that with which it was bent out of it. Hence it is evident, that the animal functions require that disposition of the muscles which we call *antagonist* muscles.

It frequently happens that the action of muscles is wanted, where their situation would be inconvenient. In such cases,

the body of the muscles is placed in some commodious position at a distance, and it communicates with the point of action by slender tendons. If, for instance, the muscles, which move the fingers, had been placed in the palm or the back of the hand, they would have swelled that part to an awkward and clumsy thickness: they are therefore placed in the arm, as high as the elbow, and they act by long tendons strapped down at the wrist, and passing under the ligament to the fingers, and to the several joints of the fingers which they severally move. In the same manner the muscles which move the toes, and many of the joints of the foot, are deposited in the calf of the leg. *See the plates.*

The number of the muscles of the human body is so great, and the circumstances which demand attention in every muscle are likewise so numerous, that a particular description of each, or even of the most important, would not at all comport with the nature of this work; we shall therefore only notice, in the words of an excellent author, the mechanical variety in the figure of the muscles generally.

It appears to be a fixed law, that the contraction of a muscle shall be towards the centre. Therefore the subject for mechanism on each occasion is, so to modify the figure, and adjust the position of the muscle, as to produce the motion required, agreeably to this law. This can only be done by giving to different muscles a diversity of configuration, suited to their several offices, and to their situation with respect to the work which they have to perform. On which account we find them under a multiplicity of forms and attitudes; sometimes with double, sometimes with treble tendons, sometimes with none: sometimes one tendon to several muscles, at other times one muscle to several tendons. The shape of the organ is susceptible of an incalculable variety, whilst the original property of the muscle, the law and line of its contraction, remains the same, and is simple. Herein the muscular system may be said to bear a perfect resemblance to our works of art. An artist does not alter the native quality of his mate-

rials or their laws of action. He takes these as he finds them. His skill and ingenuity are employed in turning them, such as they are, to his account, by giving to the parts of his machine a form and relation, in which these unalterable properties may operate to the production of the effects intended.

The muscular system would afford us numerous examples of what may be called mechanical structure: *i. e.* of such contrivances employed to attain certain objects, as a human artist would adopt on similar occasions. One of the muscles of the eye-ball presents us with a very perfect pulley; by means of which the globe of the eye is moved in a direction exactly contrary to the original application of the force. The muscle, which is called the *trochlearis*, arises from the very back part of the orbit; it has a long and slender tendon running through a pulley in the inner part of the front margin of the orbit, and then going back to be fixed in the hind portion of the eye-ball. Thus it draws the globe obliquely upwards and forwards, although the line of the contraction of the muscle is directly backward.

In the toes and fingers, the long tendon which bends the first joint, passes through the short tendon which bends the second joint.

The foot is placed at a considerable angle with the leg. It is manifest, therefore, that the flexible strings, passing along the interior of the angle, if left to themselves, would, when stretched, start from it. The obvious prevention is to tie them down, and this is done in fact. Across the instep, or rather just above it, the anatomist finds a strong ligament, under which the tendons pass to the foot. The effect of the ligament, as a bandage, can be made evident to the senses; for if it be cut, the tendons start up. The simplicity, yet the clearness of this contrivance, its exact resemblance to established resources of art, place it among the most indubitable manifestations of design with which we are acquainted.

Of Muscular Motion. Muscular motions are of three kinds, viz. voluntary, involuntary, and mixed. The *voluntary*

motions of the muscles are such as proceed from an immediate exertion of the active powers of the will: thus the mind directs the arm to be raised, the knee to be bent, the tongue to speak, &c. The *involuntary* motions of muscles are those which are performed by organs seemingly of their own accord, and without any attention of the mind, or consciousness of its active power; as the contraction and dilatation of the heart, arteries, veins, stomach, &c. The mixed motions are those which are in fact under the controul of the will, but which usually act without our being conscious that they do so, as in the case of the muscles of respiration.

As motion is produced by the muscle contracting both its ends towards the centre, when one end is fixed, the other must of course be drawn to the centre of motion, and with the bone or any other part to which it is affixed; and thus by the co-operation of several muscles, not only a limb, but even the whole body is put into action. This is the case with all the muscles of voluntary motion; their fibres contract on the application of the nervous influence, and the whole muscle shortens itself, and on this same principle the other muscles perform involuntary motion. The heart contracts from the stimulating properties of the blood; the arteries do the same; also the absorbent vessels by a similar action of their contents; and likewise all those organs and parts which have the power of acting, independently of the mind. Hence the motions of animals have been defined to be the contraction of the muscular fibre, from the presence of some stimulating influence. But it has not yet been discovered whence the muscular fibre derives this contractile power.

Of the Brain and Nerves. The *brain* is a soft and whitish substance, situated in the cavity of the skull, and corresponding in form to that cavity. Its parts are supported by a firm membrane, called the *dura mater;* and its substance is more immediately invested by a delicate membrane, called the *pia mater*. The structure of the brain is remarkably con-

stant and uniform, very seldom deviating from the accustomed standard; which seems to prove, that the right performance of the functions of this organ requires a great exactness in the structure of the individual parts. The whole brain is divided into two parts: that which is in the upper or fore part of the skull, is called the *Cerebrum;* and that which lies at the back part just under the Cerebrum, is denominated the *Cerebellum.* The *dura mater* acts as a lining to the inside of the skull, and it has three parts or processes serving as partitions to certain portions of the brain to keep it steady. The *pia mater* invests the brain even between its lobes and folds. It serves not only to contain the brain, but to support its blood-vessels, which are in this part in great numbers; that the blood may not enter the brain too impetuously, the veins also unite upon it.

There is likewise a medullary production from the under part of the two divisions of the brain, which is called the *Medulla Oblongata.* The production of this through the great opening of the skull, and down the channel of the spine, is the *Medulla Spinalis,* or *Spinal Marrow.*

It may be observed, as shewing the characteristics of the three substances just enumerated, that wounds in the Cerebrum, though very dangerous, are not mortal; but in the Cerebellum and Medulla Oblongata, they cause sudden death; and in the spinal marrow, they occasion loss of sense in all the parts which receive nerves from below the wound.

The *nerves* are soft, white, fibrous cords, that arise from the brain and spinal marrow: they come out in pairs, and are distributed through the whole body. There are forty pairs of nerves; of these, nine pair arise from the base of the brain within the skull; a tenth from the brain, as it passes through the great hole of the skull into the spine; and the other thirty pair proceed from the spinal marrow. Those arising from the brain pass through holes in the base of the skull, and are distributed chiefly to the organs situated in the head, and to those contained in the chest and belly: while the nerves, which arise from the spinal marrow go, partly among the internal organs

of the trunk, to be distributed to the exterior parts of the body, and to the extremities, or limbs.

Respecting the structure of the brain and nerves—the nature of their powers, and in what way the operations of the mind are connected with the matter of the brain, nothing yet has been ascertained. The following facts are, however, generally admitted as true: 1. The brain and nerves are sensible, constituting the organs of feeling and sensation in the animal machine. 2. All the other parts of the body derive their power of feeling and sensation from the brain, the spinal marrow, and the nerves; being in themselves wholly insensible, and made capable of feeling only in proportion as they have nervous branches distributed among them. 3. The excitement to all voluntary motion, or to those actions which are produced by the will, flows from the brain or spinal marrow, through the medium of the nerves, to those parts of the body which we wish to move. 4. The nerves are the organs, and the brain the receptacle of all our sensations, the source of all our ideas; from which it has been inferred that the brain is the seat of the soul.

CHAP. XXVII.

OF MAN, HIS STRUCTURE AND FUNCTIONS,

Continued.

Organs of Sense—Seeing—Hearing—Smelling—Tasting—Touching. Organs of Circulation—Heart—Arteries—Veins—Absorbents—Glands. Organs of Respiration—Trachea—Lungs—Diaphragm. Organs of Digestion—Stomach—Intestines—Liver, and Pancreas—Digestion as a function: The Kidneys—Integuments—Cellular Membrane and Fat. The Skin—Perspiration—Hair—Nails.

Of the Eye. The organ of vision, or the eye, is lodged, for its safety, in a socket formed partly by the bones of the skull, and partly by those of the face; and for the still greater security of this delicate organ, it is defended on the outside by the eye-lids, which serve as an occasional covering against external bodies; while a fine fluid, secreted or separated from a small gland, which is situated near the outer angle of the eye-lids, is constantly spread over the surface of the eye to keep it moist and transparent; and to wash away those particles, which, floating in the air, might produce injurious effects. This fluid, known by the name of tears, afterwards passes off by two small openings, at the opposite or inner angle of the eye, and thence descends by means of a canal,

into the nose. The eye-lashes grow out from the edges of the lids, and serve not only to protect the eye from insects, and other minute bodies continually floating in the air, but also to moderate the action of the rays of light in their passage to the eye.

Each eye-ball is partly transparent, and partly opake; the former portion transmits the rays of light to the nerve, which is spread at the back part of the eye; while the latter serves as a covering to this organ, and is intended also to confine the *humours* of the eye as they are called, and limit the passage of the rays of light. The opake part of the eye consists, first of the white outside coat, called the *sclerotica*, which covers all the back part of the globe of the eye, and running forward joins the transparent coat called the cornea, and which is placed at the fore-part of the eye. These two coats forming the outside covering or case, for containing the other parts of the eye, have been compared to the outside of a watch, the transparent part answering to the glass, and the opake part to the case in which it is fixed. It is the external and visible part of this opake coat which forms what is called the white of the eye. On the subject of the eye: its coats, humours and manner of vision, see p. 64-6 of this volume.

Of the Ear. This organ is divided into two parts, the external and internal ear, by a membrane, called *membrana tympani*. The figure and situation of the former are well known; it is perfectly adapted to collect the air; and by its curiously winding channel, to propagate sound to the internal parts. We may therefore pass on to the description of the latter.

The internal ear, which is the immediate organ of hearing, is seated within the temporal bone of the skull, and consists of cavities, labyrinths, and passages, hollowed out of its substance, together with fine membranes, as linings, some very minute bones, and the auditory nerve.

The first passage is comparatively of considerable length, which leads from the external to the internal ear; it is lined

with a fine membrane, and is furnished with numerous small hairs for guarding the parts within from the entrance of insects, &c. The inner extremity of this canal is closed by a thin transparent membrane, set in a bony circle like a drum head: under this membrane runs a branch of a nerve, and immediately beyond it is a small cavity called the drum of the ear. This cavity contains a chain, formed by four small bones; it is of a hemispherical shape, and has four openings into it: the first is a small canal communicating with the back part of the mouth; the other three are holes which open into different recesses of the ear. One of these openings leads directly through a bony partition, into what is denominated the labyrinth of the ear.

The labyrinth of the ear consists of three parts: 1. A spiral bony canal, twisted like a snail-shell, and thence called the *cochlea*. 2. Three semicircular bony canals; and 3. A small cavity called the *vestibulum*, into which the cochlea and the semicircular canals open. These parts are formed of the hardest bone in the body, and in solidity almost equal to ivory. *See the figures.*

Although we do not know the exact mode of action of this intricate but wonderful organ, it is certain that the auditory nerve, which is spread over the whole labyrinth, is the seat of the sense of hearing; and that a certain modulation of the air, conveyed through the first canal, and thence communicating its vibrations to the nerve, is the cause of hearing. The manner in which it is effected has been thus described.

Sound being created by the stroke of one body against another, causes an undulating motion in the air, similar, probably, to the circles which are formed on throwing a stone into smooth water; and these waves of the air, travelling at the rate of eleven hundred and forty-two feet in a second, strike against the external ear: here they are collected and conveyed through the canal to the membrane closing the drum of the ear. Against this membrane they strike, so as to make it vibrate, and the vibration is propagated onwards by the small

bones in the drum of the ear, till it reaches the labyrinth, where communicating its impulse to a watery fluid contained in its cavities, the auditory nerve at length becomes affected by the waves in the water, and the sense of sound is produced, on the brain.

Of the Nose. This organ is a very prominent feature in the human countenance: it is formed chiefly by the bones of the face, and communicates with the bony cells in the head. The internal part of this organ, which is the seat of smelling, is formed by the convolutions of four small bones, two in each nostril: a soft membrane covers them through all their windings, and upon this the branches of the olfactory nerve are distributed. The sense of smelling is effected by this membrane. The effluvia of bodies, consisting of their volatile particles, being carried with the air in which they float, through the nose, in inspiration, strike against the olfactory nerves which are every where spread throughout the membrane, and produce in them a certain sense of feeling, which is denominated smelling. This sense, besides adding to our sum of pleasurable feelings, is evidently intended to direct us to a proper choice of aliments, at the same time warning us to fly from such exhalations and vapours as vitiate the air, and render it injurious to life.

Of the Taste. The tongue, from the great concern which it has in the functions of mastication, deglutition, and articulation, and because it constitutes the organ of taste, presents an interesting object to the physiologist. The taste properly resides in the nervous papillæ, which lie upon the extremity and sides of the tongue, and is excited by the contact of those bodies whose properties are calculated to act upon these nerves. According as they make different kinds of impressions, we have the different sensations of sour, sweet, bitter, &c.; but according to the particular state of these nervous papillæ, with respect to moisture, that is, according as the organ is or is not in a healthy state, the taste varies.

The capability of the tongue to feel a difference of tastes,

was implanted, no doubt, that we might distinguish such food as is most salutary; for in general what is pleasant is wholesome, but that which is ill-tasted, is rarely fit for nourishment. Upon a similar principle, Nature has invited us to take necessary food, as well by the painful sensation which we call hunger, as by the pleasure arising from the sense of taste.

Of the Touch. The sense of touch is that faculty which enables us to distinguish certain properties of bodies by the feel, and which exists in all parts of the body possessed of sensibility. The term is, however, commonly confined to the nervous extremities or papillæ of the skin, which, by the peculiar sensibility of their structure, are enabled to form ideas of the solidity, moisture, inequality, smoothness, fluidity, &c. of bodies. But the part of the skin which possesses this sense most perfectly, is that covering the points of the fingers, which from the peculiar arrangement of its nervous papillæ, and the convex shape of the part on which they lie, is admirably calculated for inquiring into the nature of bodies by the feel.

Hence it may be inferred, that in each of the organs of sensation, the eye, the ear, the nose, the tongue, and the skin, there is a nerve or nerves, on which impressions can be made; and the organ itself is a sort of apparatus for conveying to the nerve a particular sensation from the impressing object. Thus the transparent parts of the eye are calculated to transmit the rays of light to the nerve, that is, the retina, which is spread behind them—the ear to collect, concentrate, and propagate the vibrations of sound, till they strike against the nerves distributed in the labyrinth—and the nose, the tongue, and fingers, are so constructed as, that the nerves, which are spread upon those parts, receive different kinds of impressions by contact, owing, perhaps, to the difference of the medium through which the nerves are acted upon. It appears then, that there is a common seat for impression in all the organs; and that the difference of sense is created by

the organ itself, whose peculiar construction is calculated to receive a particular sensation from the impressing body.

The Organs of Circulation are the heart, the arteries, the veins, the absorbing vessels and their glands. The *heart* is situated nearly in the centre of the human body, occupying a place in the chest, lying upon the muscle which divides the chest from the cavity below. In this situation the heart is sustained by the large blood-vessels that originate from its base; but its point is entirely free, and it is surrounded by a strong membranous bag, which is fastened to these vessels, and which is intended to preserve the moisture of its surface, by constantly exuding a fine thin lubricating fluid.

The heart is hollowed out into four cavities, or chambers, for receiving the blood, and for giving it a fresh impulse. These cavities are in pairs on each side of the heart. The cavities in each pair communicate with one another by an opening through the partition which divides them, but they are totally distinct from the cavities on the other side, although they correspond with them in shape, structure and use. Hence the heart may be said to consist of two distinct organs; the one on the right side for maintaining the circulation of the lungs, and the other on the left, for impelling it through the rest of the body. The first cavity on the right side of the heart is called its *auricle*, and it receives the terminations of two large veins, which re-convey the blood returning from all parts of the body, to the heart. This cavity may be considered as a reservoir for receiving the returning blood, which it immediately discharges into the other cavity on the same side, called the right *ventricle*. The opening into the ventricle is closed by a valve, which is so contrived, as to admit the blood, but to prevent its return; the ventricle itself has, however, another opening leading into an artery, and when filled with blood from the auricle, it contracts and forces it into the artery of the lungs. There are also valves situated at the commencement of the artery to

prevent the blood from returning into the cavity whence it had been expelled. The structure of the left side of the heart is very similar to that of the right; but the auricle on the left side receives the blood from the lungs by four veins which open into it, while it is the office of the left ventricle to force it into a new circulation along the whole extent of the body. The left ventricle is stronger than the right, because it has a greater resistance to overcome.

The substance of the heart is muscular; but the muscles are so arranged as to admit of contractions in all directions; and with such a modification of the irritable principle, as to be contracted and dilated alternately through the whole of life, so that the circulation never ceases. The auricles of each side are filled at the same instant, while the ventricles are at the same time emptying themselves, the right one into the artery which leads to the lungs, where the blood is changed in its colour and other properties; and the left one into the aorta or great artery of the body.

Of the Arteries. From the ventricles of the heart, as we have seen, arise two large elastic tubes called arteries, which afterwards divide like a trunk of a tree into innumerable branches. The one commencing at the right side of the heart, conveys the blood to the lungs, while that which is continued from the left, carries it to all the other parts of the body. The arteries partake of the nature and action of the heart; for being dilated and irritated by the blood, driven into them from the heart, they contract, by means of their muscular coat, upon the blood, and thus force it to all parts of the body for their nutrition and secretion. This dilatation and contraction is called the pulse, and is perceptible in the trunks, and all the main branches of the arteries.

Of the Veins. The blood, having been conveyed by the arteries to the most extreme parts of the body for its nourishment and repair, requires to be returned back to the heart and lungs to be prepared for a new circulation; for this purpose veins are provided. They commence from, or rather

are continuous with the minute arteries; and as they approach the heart, they run into larger but fewer tubes, till at last they terminate in it by six large trunks. Two of them empty their contents into the right auricle, the one collecting the blood from the vessels of the head and the upper extremities, while the other descends with it to the lower parts of the frame. These are loaded with venous blood, but the other four veins pour the blood from the lungs into the left auricle: this blood is now changed into a bright red colour, and is called arterial blood, because it has the appearance with which it is always found in the arteries; so that in the lungs, the offices of the arteries and veins are transposed, the arteries conveying venous blood, while the veins are filled with arterial blood. The veins do not pulsate like the arteries; the blood, which the former receive from the latter, flows through them very slowly to the heart, to which it is conveyed chiefly by the contraction of the muscles, and among which they branch out; it is, however, prevented from running backwards by valves, that constitute one great distinction between these vessels and the arteries.

Of the Absorbents. These are thin pellucid vessels arising from the various parts of the surface of the body, and running to a common trunk or tube, called the thoracic duct, because it lies principally in the thorax or chest, which empties itself into a vein a little before it comes to the heart. The absorbents are distinguished into two kinds, the lacteals and the lymphatics: the former absorb the nutriment from the intestines, and convey it by the thoracic duct into the circulation; while the latter vessels take up the colourless fluid, called lymph, and convey it from all parts of the body to the same point. Thus the particles, which, from whatever cause, have been separated from the red circulating mass, and thrown out by the secreting or exhaling arteries, are absorbed, after having performed their duties, and are again conducted back by the lymphatic vessels into the circulation to mix with the blood; and the lacteals, or absorbing vessels of the intestines, drink up the milky fluid formed from our food, and carry it to the

heart and lungs to be changed into blood. Hence absorption is a function necessary to the circulation, and highly essential to life; it supplies the constantly decreasing blood with new parts. Moreover the skin is full of small pores which are the mouths of the lymphatic vessels: through these are absorbed properties from the air, water, &c. which are conveyed thence into the system for refreshment, and also for the cure of diseases, as it is known that certain medicines rubbed into the skin enter the body, and affect the whole system. But the grand and universal agency of our lymphatic system is the removal of old and useless parts, in order to make room for new ones; and thus there is a general, though imperceptible renovation of all its parts, by which the health and vigour of the whole body are preserved.

Absorption also assists very materially to remove those injuries which happen to the frame by accidents; thus tumours &c. are removed by the absorbents. Fluids issuing from a ruptured vessel will be absorbed and carried again into the circulation. Even parts of the body which are diseased, or have their organization destroyed, will have the dead particles carried off by absorption, and thus make room for healthy depositions. The dark coloured spot which is left by a bruise is owing to blood having exuded from a ruptured blood-vessel; and its disappearance is the effect of the action of the absorbents, which are operating at all times, and in every part of the body, in a greater or lesser degree.

Of the Glands. The term *gland* is applied to those organs of the body, which separate from the blood conveyed to them by their blood-vessels, various substances generally of a fluid nature, and discharge them through one or more tubes, named excretory ducts. The blood is composed of various matters which chemical examination can detect and separate, and which are undoubtedly employed for the renovation of the solids and fluids of the body. It presents these to the various organs, which, by converting them into their own substance, derive the means of supplying the waste occasioned by the

natural actions of the parts, or form from them various products distinguished by new characters. The former of these processes is *nutrition* or *assimilation;* the latter, *secretion:* they resemble each other in their commencement, in which the organ by some powers of nature peculiar to living bodies, selects from the blood such principles as suit their nature and functions, but they differ in the employment of what is selected; which, in the one case, is retained and assimilated to the already existing organization, and in the other it is applied to some other purpose. Glands are of two kinds, the small and the larger.

Each small gland consists of an artery for supplying it with blood, and also for separating a particular kind of fluid from this blood; next, of an excretory duct, or canal, which conveys away the fluid thus separated; and lastly, of a vein for returning to the circulation the blood remaining after the secretion has been effected. Of this simple kind are the generality of those small glands which are found under the skin, in the nose, mouth, eye, &c.; and which by separating an oily or mucilaginous fluid from the blood, keep the parts on which they lie moist, prevent friction, defend them from the air, and the extraneous bodies that it may contain.

The larger glands consist principally of an aggregation of small ones; but they have some peculiarities of general structure. This process of separating various bodies from the mass of the blood is a most important function; for in fact every animal production is a secretion, whether there be, or not, a complicated apparatus for forming it. Thus the bone and the muscle are as strictly secretions as the bile, the tears, &c.; only in the latter case, for the purpose of compactness, or because the secretion is wanted in one spot for a specific purpose, the apparatus for producing it, is limited; while in other instances, the substances are formed in many parts of the body.

In general, the substances which are secreted by the glands are of immediate use in the animal system; but there are

substances termed execretions, separated from the blood as useless or noxious; such is the perspirable matter, and some others.

The manner in which the glands effect their secretions is wholly unknown. They are composed of similar vessels, have a common fluid to secrete from, nevertheless they separate from the same fluid, the blood, substances wholly differing from each other. The secretions themselves do not exist in the blood, although the elements do, and many of them are totally unlike to any thing in the circulating fluid; such is the bile, the fat, &c. We have seen in the chapters on Chemistry that all animal and vegetable substances are resolvable into a few simple ones; and we have also seen, that a slight variation in the proportion of the ingredients of a compound body, and such are all animal substances, will totally change the character of the newly formed matter. We may therefore infer, indeed it is a necessary consequence of what has been said, that the human body is a complicated laboratory; in which, changes the most important are incessantly taking place, partly of a chemical, and partly of a peculiar nature, resulting from the principles of life.

Of the Organs of Respiration. These are the wind-pipe, lungs, diaphragm, ribs, and numerous muscles. Respiration consists in drawing a certain quantity of air into the lungs, and throwing it out again alternately. Whenever this function is suspended, but for a short time, the animal dies.

The *trachea*, or *wind-pipe*, by which the air is conveyed from the mouth and nostrils into the lungs, is formed of cartilaginous rings, and an elastic ligamentous membrane. The rings are intended to keep the area of the circle constantly open. The upper part of the trachea is formed for producing the voice, and has a small thin cartilage placed over the mouth of the tube, which occasionally shuts down, and closes the passage of the lungs, as in the act of swallowing. From this part the air-pipe descends along the fore part of the throat, till it passes into the cavity of the chest, to enter and

be ramified through the lungs; its internal surface is kept constantly moist by a mucus, which is poured out from small glands, every where existing on the membrane lining this tube. When the air-pipe has nearly reached the lungs, it divides into two great branches; one of these go to each lung, and is distributed through the whole substance in an almost infinite number of ramifications. These small branches terminate in innumerable cells that communicate with each other, and give the lungs the appearance of a honey-comb when it is cut through.

The *lungs* are the principal organs of respiration; they are two in number, the one occupying the right, and the other the left cavity of the chest; but they respire by one common tube, the wind-pipe.

The *diaphragm* is a strong muscle that divides the chest from the abdomen; and which can act with great power in enlarging the cavity of the chest: it is convex towards the lungs, and concave below; when it contracts its surface, it becomes nearly flat, and of course the chest is deepened. At the same instant, the muscles between the ribs contract, and raise the lower ribs. When they are raised, they are so contrived as to be drawn outwards, and the cavity of the chest is dilated laterally. Thus, when we respire, the chest is enlarged in all directions. The lungs are suspended in the cavity, and follow all the motions of the parts which inclose them; for when the pressure of the ribs is removed, the air which they contain, expands by its elasticity, and the external air rushes in to restore the balance. The lungs are now in a state of inspiration, and they are emptied by the following process.

When the diaphragm contracts, it would lessen the abdominal cavity, as much as it enlarges the chest, if its loose inclosure did not give way by protruding. This protrusion excites the abdominal muscles to re-act; their contraction pushes up the now relaxed diaphragm into the chest, and as they are attached to the lower edges of the ribs, they pull them down with great power, and thus lessen the cavity of the chest. The

lungs are compressed, and the air, which they had just received, is now expelled. This is expiration.

The alternate dilatation and contraction of the chest proceed uninterruptedly from the moment of birth to the end of life; and in a healthy adult they are repeated about fourteen times in a minute, so that each act of respiration corresponds nearly to five pulsations of the heart. In the act of inspiration, a quantity of atmospheric air is received into the lungs, and retained there for a short time, when expired it is found to be altered in its composition: it has lost a large part of its oxygen, and it now contains a quantity of carbonic acid. These changes are inseparably connected with the conversion of the venous into the arterial blood; for in passing through the lungs, it decomposes the air, imbibing the oxygen, and throwing off the azotic gas. See Chemistry.

Of the Organs of Digestion. These occupy the great cavity of the abdomen, and are principally the stomach, the intestines, the liver, and pancreas.

The *stomach* is a sort of large bag for receiving the food; it is situated a little below the diaphragm, or that muscle within the body which divides the cavity of the chest from that of the abdomen, and has two muscular tubes or pipes opening into it; one of these leading from the back part of the mouth down through the chest, opens into this organ at the left side. This tube is called the *œsophagus;* it runs between the air-tube and the spine, and conveys the food from the mouth into the stomach. From the right orifice of the stomach arises the other tube, which is intended to convey away the food after a certain time; this tube constitutes the intestinal canal. From the internal surface of the stomach there is a fluid constantly secreting, called the gastric juice, which has the peculiar properties of dissolving and attenuating the food before it passes into the intestines.

The *intestines* consist of a long membranous and muscular canal, which arises from the right orifice of the stomach, and

is five or six times the length of the body which contains it, forming many circumvolutions in the cavity of the abdomen, which it traverses from right to left, and again from left to right. Soon after the intestinal canal goes out from the stomach an oblique opening may be perceived, by which the fluids from the liver and pancreas are poured into it for the purpose of mixing with the food as it passes downwards; and that the descent of the aliment may not be too rapid, by which the system would be deprived of a supply of nutrition sufficient for life and health, the inner coat of the intestine is of a villous structure, and admirably calculated to retard the progress of the food, till the whole of its nourishing properties is extracted, and absorbed by proper vessels.

The food, which is reduced by the gastric juice and by the action of the stomach into an homogeneous mass, called *chyme*, enters the intestine, where it undergoes a farther change, and becomes *chyle*. It is propelled along the canal by the muscular coat of the intestines, while the villous tunic absorbs from it the nutritious particles; the residue of the alimentary matter is sent into the larger part of the intestine, from which, in due time, it is expelled.

The *liver* is the largest gland in the body, and is intended to secrete a dark coloured fluid, called bile, and for this purpose it is supplied with a large quantity of blood. Almost all the veins of the other viscera of the abdomen, instead of sending back their blood to the heart, by the great returning veins, run forwards to the liver, where they unite in one trunk, called the *vena porta*, and which soon after enters this gland, and is ramified throughout its substance. Here this great vein performs the office both of an artery and a vein; for like a vein it returns the blood from the extremities, while as an artery, it accomplishes secretion. Besides the *vena porta*, which furnishes the materials for the secretion of bile, the liver has an artery of large size for the purposes of nutrition.

The bile, after being separated from the mass of blood in

the liver, is conveyed by very minute excretory ducts into larger ones, which also convey it into one great channel that opens into the intestine not far from the stomach. There is attached to the lower part of the liver a little membranous bag, which contains a portion of bile secreted in the liver; its neck is continued in the form of a canal, running to unite with that of the liver; when both enter the intestine, and pour in their contents by a common opening. The bile is supposed to assist in the conversion of food into chyle: it certainly stimulates the intestines to act; for when the entrance of bile into the intestines is prevented by gall-stones, or when there is a deficiency of bile, the body is constantly costive. The liver and the gall-bladder, from their situation, will be most pressed, and consequently give out most bile, when the stomach is fullest, which is the time that it is most wanted.

The pancreas, or sweet-bread, is a kind of salivary gland, and secretes a fluid by means of a duct which enters the intestine, together with the biliary canal.

Of Digestion. The food having been sufficiently divided in the mouth, by the action of the teeth and saliva, passes in the form of a pulp through the œsophagus into the stomach: here it undergoes a constant agitation by means of the abdominal muscles, of the diaphragm in breathing, and by the motion of the muscular fibres of the stomach itself. Thus, by these continued movements, every part of the food is exposed to the action of the gastric juice, which has the power of farther dissolving it, before it passes into the intestines. It remains in the stomach two hours or more, and is in that time, converted into a greyish pulp, called *chyme*, when it passes out by the right orifice of the stomach into the intestinal canal. Here, as the digested food passes along, it receives from the mouths of the ducts, opening into the intestine from the liver and pancreas, a full supply of bile and saliva. Thus diluted with these, and other fluids received from innumerable exhalant arteries, the chyme is in part changed in the intestines into a milk-like fluid, called chyle,

which is separated from the general mass, as it passes slowly along the intestinal tube, in which this milky fluid is absorbed by numerous small vessels, called lacteals: the residue, as useless to the system, is, as we have observed, carried away.

From the intestine, the lacteal vessels convey the chyle along a membrane called the mesentery, and which extends from the intestine to the spine, for the purpose of sustaining the former in its proper place. Passing through this membrane, the lacteals run onwards to the thoracic duct, lying chiefly in the chest; and which, after receiving the communicating branches from the whole absorbent system, opens into a vein near the heart. Into this duct the lacteals empty their contents, which soon after mixing with the lymph, conveyed likewise to this tube from various parts of the body, both fluids are carried along the said thoracic duct to its opening into the vein, and there are poured together into the circulation. The chyle mixing with the blood, becomes soon assimilated: from the vein where it enters, it is carried directly to the right side of the heart, where it is driven into the lungs, to imbibe the oxygen of the atmospheric air, and to part with some of its carbon. Returning to the heart again, now formed into perfect or arterial blood, it is forced by the left side of this organ along the arteries, to distribute nourishment to every part of the animal machine.

The *kidneys* are intended to drain the system of its redundant water; for this purpose a considerable portion of the blood is constantly passing into them by a branch of an artery: here it undergoes a change, having its superfluous water separated; and it is then returned to the general circulation, by means of a vein which goes to the great ascending vein of the body. The water being separated from the blood, is carried by means of canals into the bladder, where it remains till such a quantity be collected as is sufficient to induce an irritation that leads to its expulsion. The canals that convey the water from the kidney to the bladder are called ureters,

and by a very simple mechanism, they convey their contents into the bladder without a possibility of regurgitation, merely by passing obliquely about half an inch between the muscular and inner coats of that organ, which oblique entrance answers every purpose of a valve.

Of the Integuments of the Body. The human body is protected by a strong pliable and sensible covering, which not only defends the parts beneath from external injury, but gives symmetry and beauty to the figure. This covering consists of several parts, which we shall enumerate, and briefly describe.

Of the cellular Membrane and Fat. Between the skin and the muscles, or flesh, and between the fibres of each muscle, there is interposed a loose, oily substance, composed of a cellular texture and fat. The latter is fluid in the body, and is deposited in the cells of the former, for facilitating muscular motion. The cellular membrane which contains this fat, is not confined to any particular part, but exists at every point of the body. It serves as a bond of union, by tying and fastening all the parts together, yet in such a manner as not to prevent or obstruct their necessary motions. Fat is deposited very unequally throughout the body, but it is always found where it seems to be most wanted. It fills up the chinks and crevices of the muscles, and it gives that gently undulating outline to our bodies, on which the beauty of the human form depends. It undoubtedly answers many other purposes. It is supposed to accumulate in health and middle age for the supply of the system when other sources fail. Hence it is absorbed in disease, and taken up into the circulation. In old age its quantity lessens when the appetite and other functions fail.

Of the Skin. The skin of the human body consists of three separate parts or layers, which lie in close contact with each other, and adhere by means of numerous small vessels and fibres, which pass from one to the other. The first layer,

called the *cutis*, or true skin, is spread immediately upon the fatty membrane just described, and is always white, whatever the complexion may be. This skin is very vascular, and is endowed with exquisite sensibility, being supplied with numerous nerves, whose papillæ stand out, and are the seat of feeling. It is extremely elastic, as in the dropsy it will stretch out very far, and return again with health, nearly to its natural dimensions. Under the inferior surface of this skin there are situated numerous small glands, which secrete an oily fluid, poured out upon the external surface of the skin by means of excretory tubes, to keep it soft and flexible. It is this skin in animals, which, when prepared by tanning, constitutes what is called leather.

Immediately on the surface of the true skin, between it and the *cuticle* or scarf-skin, is interposed a mucous substance, on which depends the colour of the body. Externally to this mucous membrane lies the cuticle, or scarf-skin, which is a fine, transparent, but insensible membrane, every where investing the body, and is the part of the skin which is raised in the form of bladders, by the operation of fire or a blister. The use of this last covering of the body is to protect the delicate nervous fibres, which stand out from the true skin, from the external air, and to modify their too great sensibility, by interposing itself between them and the body in contact. The cuticle is perforated by innumerable pores, for the passage of the perspirable matter.

Of Perspiration. An important office of the skin, is to exhale from the body a part of the watery fluid which it contains; and for this purpose it has innumerable excretory vessels opening upon its surface. This exhalation, though frequently insensible, is perpetually going on, as will be evident, by plunging the naked arm into a long, but perfectly clean and dry glass receiver. The vessel will soon lose its transparency; and if the arm be kept in it some time, streaks of moisture will trickle down the sides of the glass. Hence it is evident, that the matter of perspiration has water for its ba-

sis, and that this water is perpetually flying off in subtle vapour; or when the action of the perspirable vessels is increased either by exercise or heat, the perspiration becomes more sensible, and is seen to exude from the skin in large quantities. One of the great uses of perspiration is to regulate the system, by keeping up a constant evaporation.

Of the Hair and Nails. *Hairs* consist of an insensible excrescence produced from the cutis. Each hair grows from a small bulb, and is lengthened by means of additions made to it in the bulb. The bulbs, when viewed with a microscope, are found of various shapes. In the head they are roundish, and in the eyebrows oval. Each bulb seems to consist of two membranes; between these there is a certain quantity of moisture. Within the bulb, the hair is separated into three or four smaller fibres. The bodies of the hairs, that is, the parts without the skin, vary in softness and colour, according to the difference of climate, age, temperament of the body, &c. They afford a light and ornamental covering to the head; and, as in the case of the eyelids and brows, serve as a defence to the delicate organs of vision; and they frequently adorn the figure by the richness of their colour, and the beautiful tresses which they form.

The *nails* are hard, and partly transparent, like horn. They seem to possess many properties in common with the scarf-skin; like that substance, they are neither vascular nor sensible; and when the scarf-skin is separated from the true skin, by maceration, or otherwise, the nails frequently come away with it. In each nail we distinguish three parts, the root, the body, and the extremity. The root is a soft, thin, and white substance, terminating in the form of a crescent; the scarf-skin adheres very strongly to this part; the body of the nail is broader, thicker, and apparently of a redder colour; and the extremity is of still greater firmness. Nails increase from the root, and not from their upper extremities. Their principal use is to cover and defend the ends of the fingers and toes from external injury, and to strengthen

those parts, and prevent their bending backwards, when applied with force against any hard resisting body.

The foregoing sketch or outline respecting the structure and functions of the human body may, it is presumed, with the subjoined plates, be considered as an introduction to a study, that cannot fail to be interesting to young persons, who have had no previous opportunity of considering the subject. It will also, it is hoped, be considered as a proper introduction to Dr. Paley's work, on "Natural Theology," which cannot be recommended too strongly. Those who would enter farther into the subject of Anatomy, and yet who do not pursue it professionally, will find an interesting article in Nicholson's British Encyclopædia; and a still larger account, in a work entitled "The Popular Compendium of Anatomy, &c. By William Burke." To both these, as well as to the "Natural Theology," this part of our own volume stands considerably indebted. *See plates on this subject at the end of the volume.*

A LETTER

From a Father to his Son, on the Evidences of the Truth of the Christian Religion.

MY DEAR SON,

YOU will not be surprised, that in the present circumstances I address you in a tone more serious than usual. In the course of a few days you will quit the parental roof; and, free from the immediate restraint of a father's authority, you will enter into a situation in life in which your conduct will be necessarily left in a great degree to the guidance of your own discretion. Though I have happily no occasion to question the general excellence of your dispositions, your natural good sense will suggest to you that this is to me an anxious moment. May I indulge the hope that you participate in my feelings? Elated as you in all probability are, at the prospect of extended freedom and independence of action, I could wish you to pause for a moment before you commence your new career, and maturely to reflect upon the perils to which you will soon be exposed. The hazards to which inexperienced youths are subject, on their introduction to an extensive intercourse with the world at large, constitute a subject of daily remark, and afford a copious theme to the moralists with whose writings I have endeavoured to render you familiarly acquainted. With a view of obviating these hazards, I have not only inculcated upon you the precepts of the moralists in question, and from time to time, as occasions occur-

red, pointed out to you in living instances the evil consequences resulting from an early indulgence of vicious propensities,—but I have also endeavoured to enforce my admonitions on moral topics by what I regard as the sacred sanctions of the Christian Religion.

I foresee, however, the possibility of your being, occasionally at least, obliged to mix in societies in which these sanctions are not treated with the respect to which you have been taught to think them entitled. In the intercourses of life you will, in all probability, meet with individuals, if not with classes of the community, by whom the system of Christianity is not held in the reverence which is due to it, if it is in reality what its first founder declared it to be, a code of laws for the direction of human conduct, derived from the inspiration of the Deity, and established by divine authority, as enforced by the revelation of doctrines too sublime in their conception to be attained by the boldest flights of unassisted reason. With persons of this description I do not wish you to provoke any avoidable discussion. Even with respect to those who entertain serious views, experience proves that it is extremely difficult to carry on religious controversy with candour and good temper; and as to the flippant and profligate polemic, I could not wish you with such a character, unnecessarily to enter even into the intercourse of hostility. I should be sorry, however, were you, on just occasions, to decline the contest through want of the necessary weapons of defence. Still more concerned should I be, were your own belief in the truth of Christianity shaken, in consequence of your ignorance of the nature of its Evidences. On this account I think it my duty as a parent to lay before you a sketch of those Evidences, which I must desire you to read with care, and to examine with impartial, but with serious attention. I say emphatically, with serious attention. For though the principles of Religion are subjects of rational inquiry, in a most important particular they differ in quality from the abstract truths of the Mathematics. In the investigation of the latter, nothing is requisite

but a clear head—to the profitable discussion of the former, it is necessary that acuteness of understanding should be united with ingenuousness of heart.

In stating the evidence which has been adduced in proof of the divine origin of Christianity, I would in the first place propose this preliminary inquiry—is there any thing antecedently improbable in the assertion upon which it rests its claims to the notice and belief of rational beings? The Christian religion is founded upon the assumption, that at a certain period the human race were grossly ignorant of the great principles of moral and religious duty; and that, prompted by his essential benevolence, the Deity vouchsafed, by an extraordinary interposition of his providence, to dispel that ignorance by the special communication of the most sublime and momentous truth. Now, is not the former part of this assumption justified by the fact?—Is not the latter strictly consonant with the purest and the most enlightened notions which have ever been conceived of the nature of the Godhead?

In reply to the first of these questions I would appeal to your recollection of History; I would refer to your knowledge of the sentiments and conduct of the ancient world. I believe it is at present universally acknowledged, that right apprehensions of the being and attributes of God are essentially necessary to that sense of our subordination to his will, and to that acquaintance with the general laws of his government, which constitute the surest foundation of the principles of morality. And how vague and indistinct, how degrading and how impious were the notions of the ancients upon this, the most important of all the topics which call into exercise the faculties of the human mind! To say nothing of the idolatrous worship, which in the earlier stages of society, and in the less civilized states whose history has descended to modern times, was paid to the heavenly bodies, to the element of fire, to beasts and fishes, to the vilest reptiles, and even to the workmanship of human hands—reflect for a moment upon the state and the

extent of religious knowledge in the polished republics of Greece and Rome. However elegant may be the received mythology of those nations, when considered as a play of the fancy, and as adorned by the fictions of the poets, what rational being can now contemplate it, with any other sensations than those of surprise and humiliation, when regarded as interwoven, as a subject of faith, into the texture of the civil institutions of the most powerful and the most enlightened communities which existed on the surface of the globe? The religious notions of the ancients were debased by the gross errors of polytheism. Whatever might be the private opinion of the solitary speculatist, the people at large paid adoration to "the deities of a thousand streams and a thousand groves."* By the caprices of a fertile imagination, or by the terrors of superstition, to their credulity, deities were multiplied without end. And as they ascribed to the Gods, which were the subjects of popular belief, the most lamentable feelings, and the most degrading passions of humanity, the rites of their worship were in some instances ridiculous by their folly; in others, disgusting and horrible on account of the vices and cruelties which were practised in their performance. Whether the true believer celebrated the games of Flora, or whether on some pressing emergency he anxiously traced the destinies of the Republic in the palpitating entrails of a human victim, religion was to him the incentive to criminal indulgences, and to atrocities of the blackest dye.

And as religious ceremonies constituted in the heathen world a part of the civil institutions of the states in which they were respectively observed, this circumstance presented an invincible bar to religious reformation. It was deemed by the ancients so decidedly the dictate of policy to support the institutions of their ancestors,—that men of the most enlightened understandings regarded it as their duty, implicitly to conform,

* Gibbon's History of the Decline and Fall of the Roman Empire, vol. I. p. 47, octavo edition.

in religious matters, to the prescriptions of the civil magistrate. Hence the revolting spectacle of the infidel priest leading in solemn procession the credulous multitude, and uttering for their professed benefit, those praises and prayers which were to himself the secret subjects of scorn and contempt. In these circumstances the researches of philosophy were of little or no utility. They were refined, obscure, and subtle in their process, and terminated in results which were by no means distinct, or satisfactory to the inquisitive mind. The nature of the Deity was a theme which eluded the comprehension of the most sagacious, who, in treating of such high matter, lost themselves—

> " In thoughts above the reaches of their souls."

Thus bewildered and perplexed, the most fashionable sect of philosophers cut the Gordian Knot of metaphysical difficulty; and, denying as they did the agency of the Divinity in the affairs of this lower world, they disguised their speculative Atheism, by a ready conformity to any system of religious rites in which the occurrences of life called upon them to participate. Thus, as Mr. Gibbon has concisely stated the fact, the various modes of worship which, before the birth of Jesus, prevailed in the heathen world, " were all considered by the people as equally true, by the philosopher as equally false."* And when he adds to this statement, that they were regarded " by the magistrate as equally useful," he intimates his opinion, and in that opinion he is decidedly correct, that the great and the powerful among the ancients looked upon religion in no other light than as an engine of civil policy, as a means of infusing salutary terror into the vulgar, but a subject of contempt to men of cultivated understanding.

In strict connexion with right apprehensions of the being and attributes of God, a belief in a future state of moral retribution may be mentioned as holding out a most powerful encouragement to the exertion of virtuous principles, and as

* Decline and Fall, vol. I. p. 46.

operating by a most salutary restraint on vicious propensities. But in reference to the heathen world, on this topic also, scepticism and infidelity prevailed amongst the more intelligent and the higher orders of the community. Nor were this scepticism and infidelity confined to the superior classes of society. On the subject of a future state, the lowest vulgar might perhaps be abused by the vain dreams of an undisciplined imagination, which are displayed in the records of the heathen mythology. But these puerile conceptions were too gross to impose upon the general mind. The language of popular poetry is the vehicle of popular sentiments. And what topic is more frequently touched upon by the poets of antiquity, than the various feelings which are naturally excited by the "eternal sleep of death," to which they regarded every human being as doomed by the necessity of nature? In addition to which, I would call to your recollection the deliberate profession of his disbelief in a future state made by Julius Cæsar in the open Senate, in his celebrated speech against the infliction of capital punishment on the accomplices of Catiline. The historian who records this profession, does not stigmatize it with any mark of reprobation; nor does he intimate that it was received with any tokens of alarm or surprise. In short, it was nothing more than the current sentiment which constituted the fashion of the day.*

When we consider how difficult it is, even with the aid of the most awful sanctions, to restrain that impetuosity of the passions which continually tends to impel mankind to evil, what unhappy results must be expected where these sanctions are wanting? And it will be found upon inquiry, that however

* I speak of this profession as having been actually made by Cæsar, as Sallust was his contemporary, and had the means of becoming acquainted with the leading topics of his speech. If it be said, that like the orations of Livy and of other ancient historians, it is merely the production of fancy, still it may be observed, that an author of Sallust's eminence must have written in character, in consistency with the habits of the persons and times of which he treats. In either case my argument holds good.

sinister may be the conjectures which force themselves upon the mind on the statement of such a case, they are fully justified by the actual condition of the heathen world antecedently to the birth of Jesus, as it is described by the pen of the impartial historian, of the indignant satirist, or of the patient investigator of the moral state of mankind. On this subject a melancholy abundance of materials would enable me to enlarge. But I willingly spare your feelings the recital of the particulars of atrocity and guilt. You are sufficiently conversant with the writings of antiquity to be well aware, that at the period to which I allude, the consequences of a wretched theology were, as the learned Mosheim asserts, "an universal corruption of manners, which discovered itself in the impunity of the most flagitious crimes." Whosoever is intimately acquainted with the public and private history of the proud Republic, and of the nations subject to its dominion, which, at the time of the birth of Jesus, constituted the whole of the civilized world, will be obliged to confess, that the odious picture of their manners and conduct presented in the first chapter of Paul's epistle to the Romans, dark as it is, exhibits the faithful colouring of truth.

Such being the condition and circumstances of mankind at the period immediately antecedent to the Christian æra, is there any thing inconsistent with the notions respecting the Deity entertained by the most intelligent theists, in the assertion, that he then interposed to dissipate the darkness which was spread over his moral creation, by the diffusion of the rays of truth? The instruction of the ignorant, and the reformation of the guilty, are regarded as the most exalted aims; and when effected, as the happiest and the most glorious results of human intellect. The man who, even on the smallest scale, exerts his talents for the promotion of this worthy end, is deservedly held by the wise and good in high esteem. By this criterion we must decide upon the imputed conduct of the Deity. As a moral agent, we can only humbly judge of his operations by that sense of moral rectitude, which he has either primitively impressed

upon our minds, or which he has enabled us, by the cultivation of our intellect, gradually to acquire. If it be granted then, as I apprehend it must be granted by those who maintain the principles of the purest Theism, that God is eternal truth, and that his benevolence is unbounded, what condition or predicament of human existence can be imagined as more likely to give occasion to his gracious interference, than a state of the most deplorable ignorance? What gift can be conceived more worthy of his benevolence to bestow, or more fit for his rational offspring to receive, than the communication of a knowledge of his nature and qualities, and of his supreme will and pleasure—that is to say, of their duty as rational, moral, and accountable beings?

I trust, my dear Son, that upon due consideration, you will find nothing unreasonable in the abstract idea of an such interposition as I have described. On the contrary, I trust that you will be convinced that the probability lies on the side of its occurrence. It would be inconsistent with the profound reverence which we owe to the Divine Being, to say that it was incumbent upon him thus to interfere: but this we may safely assert, that the notion of such an interference on his part, is in exact harmony with the notions of his attributes which we gain by the contemplation of his works, and by our sense of the operations of his providence, as exemplified in the particular and in the general history of Man.

But shall it be said, that the instruction of mankind upon the momentous subject of their duty and expectations as moral agents, is indeed an interposition worthy of the Deity; but that in the effecting of this gracious and glorious purpose, it cannot be reasonably supposed that he would adopt any other than ordinary means? I state this objection at once in its most forcible and in its least offensive form. For with regard to those who deny in the abstract, the possibility of all miraculous interposition on the part of the Deity; in thus limiting the divine power, they are chargeable with a presumption so unbecoming the veneration with which Man

ought at all times to look up to his Maker, that I have little apprehension of the impression which their opinions may make upon your mind. You are well aware that no idea can be conceived as limitable of the divine power, which does not, in the very terms of its expression, involve a contradiction. But there is certainly no contradiction in the supposition, that the Being who created, can destroy; or that He who framed, in his ineffable wisdom, those general laws by which this lower world is governed, has the power, for the furtherance of some benevolent purpose, to suspend, and even to alter them at his pleasure. Granting then that special and miraculous interpositions on the part of the Deity are possible, I would recur to the query which I lately proposed. I would modify and extend that query. I would ask, did there occur at the time when Jesus was born "*dignus vindice nodus?*" Did a state of things then occur, which rendered the miraculous interposition of the Divine Being probable?—In answering in the affirmative, I must remind you, as the grounds of my opinion, that the moral disease, with which mankind were then afflicted, was a desperate one, and seems to have required the application of uncommon remedies—that ordinary means had been found decidedly inadequate to the accomplishment of the desired effect—and that therefore, in reference to the unbounded power of the Almighty, as exerted in strict conjunction with his other attributes, there is nothing contradictory to the sound principles of right reason in the persuasion, that in the mission of Jesus he specially interposed for the communication of moral and religious truth.

That he did thus interpose, is the main and leading assertion contained in those books of the New Testament, which are generally received among Christians as of canonical authority. Had this assertion been in the terms of its enunciation manifestly absurd, or inconsistent with the known principles of the divine agency, its authority would not have merited any attention approaching to a detailed examination. The question as to its correctness or incorrectness would have

been, *à priori*, decided at once. But in the persuasion that the way to further investigation has been cleared by the previous consideration, not only of the possibility, but also of the probability, of the special interference of the Divine Providence for the diffusion of the true principles of religious belief, I shall proceed to point out to your notice the general heads of the evidence which has been adduced, to prove, that by such interference the Christian system was propounded and established.

The first step of our extended inquiry will be a brief examination into the authenticity of the record to which Christians appeal in vindication of their persuasion, that Jesus of Nazareth is "the Way, the Truth, and the Life"—that he was specially commissioned by the Deity to communicate to mankind a pure system of religious belief, and a perfect code of laws for the regulation of moral practice. The record in question consists of the four gospels, containing the history of the birth, the early years, and the public ministry, of Jesus —of the Acts of the Apostles; or the transactions, the labours, and the sufferings of his first disciples—and of the Epistles, or public and private letters of his immediate successors, which exhibit an exposition of the leading doctrines, and of the important principles which, with a view of promoting the moral and spiritual improvement of mankind, he thought it necessary to inculcate. That these books are genuine, that they were really composed by the authors whose names are prefixed to them, is evinced from the following considerations: —that they are referred to as the admitted rule of faith and practice by the most ancient writers upon Christian theology, commonly known by the appellation of "the Fathers,"—that they are thus quoted by the successors to these writers in after-ages, in an unbroken series, down to the latest times—that under the above-mentioned description their arguments were impugned by the first enemies of the Christian doctrine, and defended by its earliest friends. Even the collision of sects, which has been unreasonably alleged as matter of reproach to the Christian profession, collaterally furnishes a satisfactory

proof of the genuineness of the received scriptures of the New Testament. For, generally speaking, however these sects may differ, they refer to those self same scriptures as authority for their various tenets; whilst that unremitted watchfulness, which was the result of their mutual jealousy, precluded the possibility of falsification, or of any material error in the exemplification of those records, which were the subjects of constant examination and discussion. In short, whosoever receives as genuine the received copies of the histories of Thucydides or of Livy, or of the Letters of Cicero, or the Younger Pliny, must upon the same principles, but upon much stronger grounds, acknowledge as genuine the received copies of the books of the New Testament.*

This point indeed is so clearly ascertained by the learned labours of judicious divines, that it has never been any otherwise than very faintly controverted. I shall proceed then to assist you, my dear Son, in discussing another very important topic of consideration, namely, the claims of the evangelical historians to credit on the part of reasonable, intelligent, and impartial inquirers. Now these claims must rest upon exactly the same principles as those of other historians and biographers, or of other narrators of alleged facts. This is a circumstance which is too frequently overlooked by the over-weening zeal of faith, and the decisive flippancy of infidelity. It is, however, in my opinion, an incontrovertible maxim; and as such I shall

*With respect to the Canon of the New Testament, it has been justly observed by Dr. Paley, that "Christian writers and Christian churches appear to have soon arrived at a very general agreement upon the subject, and that without the interposition of any public authority. When the diversity of opinion which prevailed, and prevails among Christians in other points, is considered, their concurrence in the canon of scripture is remarkable, and of great weight, especially as it seems to have been the result of private and free inquiry. We have no knowledge of any interference of authority in the question, before the council of Laodicea in the year 363. Probably the decree of this council rather declared, than regulated the public judgment, or more properly speaking, the judgment of some neighbouring churches, &c." Paley's Evidences, vol. I. p. 166.

endeavour to apply it to the case now under examination. And in the proposed application, there immediately suggest themselves to the mind two leading queries—Regarding the truth of Christianity, as mainly resting upon the credibility of the four evangelists, what opportunities had they of becoming acquainted with the transactions of which they give an account? —and from what appears of their characters and dispositions in their writings, and in their individual history, by what views and dispositions were they actuated in composing the works which are circulated under their names? To state the question more shortly, were they themselves deceived as to the events which they record; or did they wilfully, and for crooked purposes, set about to deceive others?

In reference to the first of these heads of inquiry, it is obvious to remark, that Matthew and John were of the number of the chosen friends and associates of him, whose history they relate.

They were constant attendants on his ministry.

They accompanied him from place to place.

They were the witnesses of all his proceedings.

In public they were uniformly found attendant upon his person; and when, either for the purposes of safety, or with a view of checking the zeal of worldly-minded ignorance, he withdrew, as he frequently did, from the gaze of the multitude, they were the habitual companions of his retirement. Thus they were not only auditors of his public discourses, but participators in his private instructions, and depositaries of his most secret thoughts. It is perhaps impossible for human ingenuity to conceive of more numerous and more signal advantages for obtaining a knowledge of the facts of individual history than those which were possessed by the two evangelists, Matthew and John: and it has been observed by Dr. Paley, with his usual acuteness, that their testimony is greatly strengthened by the consideration, that they wrote "upon a subject in which their minds were deeply engaged, and in which, as they must have been very frequently repeating the

accounts to others, the passages of the history would be kept continually alive in their memory."*

The gospels of Mark and Luke do not stand upon the same grounds in point of authority as those of Matthew and John. They were not composed by eye-witnesses of the facts which are detailed in them. But their authors lived in habits of strict intimacy with some of the actors in the transactions which they record. They had frequently and diligently traversed the country, where those transactions are alleged to have taken place; and had enjoyed the most unrestrained opportunityof investigating their truth. In addition to all which it may be observed, that there is in the works of the four evangelists, such a consistency in the thread of the story of the foundation of Christianity, such a harmony in the narration of the principal facts, slightly varied by trifling differences in the recital of minute particulars, precluding the very suspicion of a deceitful combination, as stamp the whole with the impress of honesty and good faith. "Hi de quibus agimus scriptores," says the learned Grotius, "credenda eadem inculcant, eadem dant præcepta: etiam de Christi vitâ, morte, reditu in vitam, summa ubique est eadem. Quod vero ad exiguas aliquas circumstantias et ad rem nihil facientes attinet, facillimè fieri potuit ut non desit commoda conciliatio, sed nos lateat, ob res similes diversis temporibus gestas, nominum ambiguitatem, aut hujus nominis aut loci plura nomina, et si quid his simile est. Imo hoc ipsum scriptores illos ab omni doli suspicione liberare debet, cum soleant qui falsa testantur de compacto omnia narrare; ut ne in speciem quidem quicquam diversum appareat."† [Grotius de Verit. Relig. Christ. Lib. III. § XIII.]

* Paley's Evidences, vol. I. p. 135.

† The writers in question inculcate the same doctrines, disseminate the same precepts: they agree too in substance in their account of the life, death, and resurrection of Christ. As to certain minute and unimportant matters in which they seem to differ, it may easily be supposed that their accounts might be reconciled, were we more distinctly informed. Their apparent discrepancy may arise from similar transactions

The conviction of the intelligent reader as to the good faith of the evangelic writers, will be strengthened by an attentive examination of the style and manner of their respective compositions. Those compositions present no mystical or abstruse speculations, such as proceed from the vain imagination of the visionary—no bursts of passion, the ebullitions of that enthusiastic temperament, which in the self-delusion of zeal, tempts the ardent partisan to transgress the bounds of truth. They contain a plain, circumstantial and unadorned relation of facts, accompanied by moral precepts, which however excellent they are found to be when tried by the touchstone of the soundest reason, are propounded with the voice of authority, and are neither supported by long deductions of argument, nor set off by the fascinating powers of language. The distinctive peculiarities of the four Gospels may be accounted for, and explained, upon principles at once satisfactory in themselves, and corroborative of their credibility, by a reference to the peculiar views and circumstances of their several authors. Thus Matthew, who wrote for the special purpose of awakening the attention of his countrymen to the claims of Christianity, industriously touches upon those topics which are likely to make a favourable impression upon the minds and feelings of Jews; whilst the Gospel of Luke is obviously calculated for the perusal of the Gentiles. The plain understanding of Mark leads him to confine himself to the more palpable passages, if I may so express myself, of the life of Jesus; whilst the speculative mind of John dwells upon the more recondite and figurative of his Lord's discourses. In short, the more minutely the biographical memoirs of Jesus, as recorded by the evangelists, are scrutinized and compared together, the more abundant are the proofs which

having taken place at different times, from the ambiguity or the multiplicity of names of men and places, and such like. And after all, this very circumstance tends to free these writers from all suspicion of collusion: for witnesses to falsehood usually agree so minutely in their testimony, as not to exhibit even the semblance of discrepancy.

present themselves of the honest persuasion of their authors, that the story which they related was true.

And this persuasion is still more signally evinced, in the conduct of these witnesses of the transactions in which Jesus was engaged during the course of his public ministry, and in the deportment of their companions, associates, and immediate successors, who enjoyed such peculiar advantages for the verification of the facts upon which the proof of the divine origin of Christianity must ultimately depend. Their course was truly arduous and perilous, and nothing could have enabled them to persevere in it, but the consciousness of upright intentions, united with a conviction of the high importance of the office which they had undertaken, as disseminators of a new system of religious faith and practice. At the very outset of their mission they had to encounter the most formidable prejudices on the part of their countrymen. The Jews were devotedly attached to that ritual which they had received from on high, by the medium of Moses, not merely through that reverence which is obviously due to institutions of divine appointment, but also in consequence of the narrow and exclusive operation of that bigotry which induces the selfish and the prejudiced to regard with contempt and abhorrence all those who do not rank with their particular sect and party. And though the populace, awed by the sight, or by the fame of the miracles wrought, or said to be wrought, by Jesus, for a time believed that he was the promised Messiah, whose advent was at that time most confidently expected by the Jewish nation, they were no sooner undeceived in their notions of his temporal authority, and apprised that the scope of his views was not bounded by the narrow confines of Judea, than they concurred with their rulers in impeaching him of a design to overthrow the institutions of his country, and in dooming him to a death, appropriated to the vilest of malefactors. Against this violent procedure, his immediate followers deemed it their duty to enter their protest. They did protest against it in defiance of

the subtle malice of the chief priests, and the rage of the multitude. In the memorable declaration that "by wicked hands" their master "had been crucified and slain," they openly characterized it as a legal murder. At the same time, in proclaiming the fact of his resurrection, they must of necessity have irritated his persecutors by all the mortification of that severe disappointment which they could not but feel, at the idea of their having derived no advantage from the sanguinary measure of his execution. The events which ensued, were such as in similar circumstances might naturally have been expected. Obliged, as the apostles were, to forego all the emoluments, pleasures, and gratifications incident to common life, and to devote themselves to the incessant activity and toil of earnest and laborious preaching, at every step in their progress they were called to encounter the virulence of the ecclesiastical rulers of the Jewish nation, and to testify the sincerity of their own belief in the principles which they inculcated, by opposing the "firmness of high resolve" to the rage of persecution. Suppose them to be fully and feelingly convinced of the truth of these principles, (which, I would remind you, my dear son, as a matter of high importance in this discussion, mainly depended upon matters of fact, not of speculation,) and their conduct is easily and naturally to be accounted for. On the contrary hypothesis their behaviour is directly and decidedly contradictory to the most clearly ascertained laws of human nature.*

* This course of argument is thus expressed in his quaint and original, but striking manner, by the late Rev. Robert Robinson, of Cambridge: "Are you aware what a dangerous task a man would undertake, who should presume to deny, either that the gospel is good, or that though it be good, yet it was not inspired by God? If it be not good it must be wicked: but what order of bad men could write such a book? Do you know any ignorant people who could do so? Is it conceivable that misers or drunkards, or swearers or liars, or any other sort of profligate people, could or would compose such a book as this? It is above their virtue, and above their invention. No. The gospel is not the production of such men. Matthew was not a blasphemer of

The author of the Acts of the Apostles, in speaking of the sentiments of a Roman governor concerning certain religious controversies, intimates that "Gallio cared for none of these things," Mr. Gibbon, in treating of the genius of the religious institutions of ancient Rome, has justly observed, that "the devout polytheist, though fondly attached to his national rites, admitted with implicit faith the different religions of the earth;" and that "the Greek, the Roman, and the barbarian, as they met before their respective altars, easily persuaded themselves, that under various names, and with various ceremonies, they adored the same deities."* On a cursory view of the sentiments of the heathens on the subject of religion, thus tending to general toleration, it might have been expected, that on the introduction of Christianity, the Roman government would have suffered the disciples of the new sect to pursue their course without molestation. But a nearer inspection of the circumstances of the case will evince a striking discrepancy between the Christian faith and the received systems of theology, which led to a reception of the former very different from the mutual welcome which was extended to the latter. In the first place the principles of Christianity were promulgated, not as the mere deductions of human reason, or as the result of political convention, but as the express dictates of the Deity himself. Hence it followed, as a necessary consequence, that the faithful supporters of those principles were precluded from any compromise with the erroneous belief, or any participation in the unholy rites, which, at the period of their earliest dissemination, were prevalent throughout the heathen world.

God; Mark was not a slanderer of mankind; Luke was not a stupid, ignorant man; John was not an artful propagator of false and idle tales. Would the profligate forsake father and mother, and houses and lands,—would the wicked expose themselves to poverty and ridicule, and imprisonment and death, to give credit to a lie? If the book were written by good men, then it was inspired; for the writers expressly state that it was not they who spoke; but the Holy Ghost who taught them what to say, &c. Robinson's Discourses, p. 66.

* Gibbon's Decline and Fall, vol. i. p. 47, 48,

For, charitable as is the genius of Christianity in relation to the feelings of kind affection which ought to glow within the human bosom, its creed is simple, precise, and susceptible of no modifications. Its fundamental doctrine, the unity of the Godhead, was directly at variance with the comprehensive, but absurd ideas of the polytheist. Nor did the state of society allow the professor of Christianity to suffer this doctrine to lie dormant, as it were, in his own breast, as a mere speculative opinion. Fully entering into the sentiments of the Jews concerning the odious nature and the dangerous tendency of idolatry, he deemed it a point of duty to bear open testimony against those public observances which were closely interwoven into the texture of the civil polity, to the institutions and laws of which the ruling powers regarded him as amenable. This circumstance involved him in daily acts of hostility against received practices and established customs, which could not but issue in his worldly disquiet, detriment, and ruin. The festivals of their nation, and even the table of conviviality, which to the people in general, were the sources of amusement and delight, were, to the disciples of Jesus, occasions of severe trial, and of bitter distress. The organization of the polytheistic system introduced to the genial board that homage to fictitious deities, which to consistent Christians was the subject of unmixed abhorrence. In refusing to participate in this homage, and still more in expressly and firmly condemning it, they shocked the prevailing prejudices; they acquired a character of gloomy misanthropy, and incurred the odious imputation of hostility to the Gods and to human kind. Thus they became, as might naturally be expected, the objects of general reproach and hatred. Their motives were misunderstood; their actions were misrepresented, and they were alternately distressed by the importunity of compassionate reproach, or harassed by the malignant activity of enmity. This was the lot of all professing Christians: but peculiar hardships awaited those of their number who diligently employed themselves in inculcating what they regarded as the maxims of divine truth.

Attracting the gaze of the multitude, and awakening the attention of the civil magistrate, they were doomed, in the course of their labours, to encounter the hasty outrage of popular fury, or to bow their heads to the more deliberate and regular infliction of the penalties of the law. Arraigned before judges insensible of the value of the principles which they maintained, and by which they were supported in the extremity of trial, their consistent firmness was condemned as the perverse folly of obstinacy; and many of them were doomed to sufferings, at the recital of which humanity shudders with horror. Now what could possibly have induced the early professors of Christianity to forego those worldly prospects, which to the eye of the generality of mankind, open so bright and fair? What could have persuaded them to give up the dearest gratifications of the social state, the applause of their fellow-citizens, the favour of the great, the love of their relatives, and the attachment of their friends?—What could have urged them to forego these dear delights, and cheerfully to subject themselves to contempt and odium, and to embrace a life of labour and sorrow, in which

"The world was not their friend, nor the world's law."

—What could have induced them to make these sacrifices, but a high sense of duty, the consciousness of upright intentions and purity of principle, and that persuasion of the divine blessing being extended to their labours, which was the result of the deliberate and settled conviction of their own minds. In conjunction with these splendid circumstances of their history, call to mind the strict morality which they invariably inculcated, and the testimony which was given by their very judges, to the innocence of their lives;* and then if you entertain the notion, that in asserting the alleged facts upon which the system of Christianity is founded, they knowingly

* See in particular the declaration of the Younger Pliny, that the Christians who were brought before him in Bithynia, had entered into a mutual compact to allow themselves in no crime or immoral conduct whatever.

and wilfully asserted so many falsehoods, you will be reduced to support the monstrous proposition, that "they were villains for no other end but to teach honesty, and martyrs without the least prospect of honour or advantage."*

In order, indeed, to form a just criterion of the credibility of the Christian religion, its external and its internal evidence should be considered in strict connexion. The existence of such a religion is a prominent fact in the history of the human race: and it is the duty of the upright and intelligent inquirer, not only to examine under what authority it was promulgated, but also whether its doctrines and its precepts are fit for God to inculcate, and for man to receive. For, as on the one hand, no authority can justify immorality of conduct as of divine obligation, so, on the other, the purity of a religious system may reasonably be alleged as a strong corroboration of its other claims to a divine origin. And in pursuing this branch of the inquiry, I would remind you, my dear son, of what I have already had occasion to observe, that right apprehensions of the Deity constitute the foundation of every thing that is valuable in religion. Now how obscure and doubtful, as I have before remarked, were the notions of the heathens concerning the existence and the nature of God. Instructed, as we are, in our early days, to trace the hand of God even in these his "lowliest works," it appears to us to be a clear and incontestable maxim, that they "proclaim their great original," with a most convincing voice. But, on referring to the annals of history, we find, that in point of fact the contemplation of the divine works had not, antecedently to the birth of Jesus, produced this effect upon the sentiments even of the inhabitants of the most civilized portions of the globe. It should seem that the Divinity was an object too vast and too sublime for the reach and the comprehension of unaided reason; and mankind in general, involved in the inconsistencies and absurdities of superstition,

* Paley's Evidences, vol. I. p. 145.

limited their religious views to the offspring of divine power, and paid to creatures that reverence which is due to the Creator alone.

And even the apprehensions which the Jews entertained of the Divine Being, were partial and inadequate. To them He appears to have revealed Himself in a manner comparatively obscure. The Jewish dispensation was, no doubt, well adapted to the nation and the times for which it was intended. But to his ancient people, God chiefly manifested Himself as a God of power. The ignorance and the superstition which prevailed in the neighbouring nations, seem to have rendered it expedient for Him to appear to them in the splendour of his terrors; and to require from them a series of rites and ceremonies which were calculated to keep Him as it were continually before their eyes. This process was no doubt requisite to preserve a gross, an ignorant, and a self-willed people from deviating into the practices of the prevalent idolatry. Still the Judaic code was imperfect; and it is in strict consistence with our ideas of the divine wisdom to believe, that in the lapse of ages it was destined to give way to a superior system. And, when compared either with the Jewish or the heathen creed and ritual, how pure, how spiritual, and, in the strict and genuine sense of that much abused word, how philosophical are the ideas which Jesus promulgated concerning God, and concerning the worship which is alone acceptable to the Divine Being. He taught that there is one Deity alone, the creator of all things visible and invisible, the sovereign of the universe, most wise and powerful, holy, just, and good—that to this Deity man owes that homage of mental veneration, which, precluding every tendency to superstition, is in scripture phraseology expressively denominated "worshipping in spirit." In representing God as the Father of the human race, he at once declared in the most intelligible terms the nature of our relation to Him, and laid the foundation for that trust in his providential care, and that hope in his mercy, which tend to

excite our gratitude, to encourage our virtuous dispositions, and to promote our cheerful compliance with his requisitions. And I would propose it as a consideration of high importance, that these principles he inculcated, not like the heathen sages, merely occasionally, and in his happier moods of thought, but uniformly and constantly. His discourses exhibit the purest theology, the most sublime and affecting views of the Deity, "unmixed with baser matter;" whilst his doctrines respecting the Resurrection, and a future state of retribution, are so precise, as to preclude, in the minds of his disciples, all doubt on this momentous subject; and at the same time so generally expressed, as to exclude every idea which is inconsistent with the solemnity and awfulness of the topic.

Strictly connected with a knowledge of our duty to God, is an acquaintance with our duty to our fellow men and to ourselves. All other studies ought, as it were, to center in this, and are valuable in proportion as they enlighten our understandings, so as to enable us to see what conduct becomes us as rational creatures, or as they tend to meliorate our hearts, and to elevate us beyond the sway of the baser affections. Influenced by these considerations, in times of old, men of great abilities and of excellent dispositions, have investigated the nature of virtue; and have inquired what is the chief good of man. Their researches into these subjects have been earnest, painful and laborious. But notwithstanding their diligence, their ingenuity, and even their integrity, they have not been able to keep clear of hesitation and uncertainty; on which account, even when they do not, as they often do, fall into dangerous errors, their moral precepts frequently appear in a very questionable shape. But when the people heard Jesus explaining to them the principles and the particulars of their duty, expressing the dictates of their immediate feelings, they characterized his language as that of "one having authority." His instructions were plain and convincing. They carried with them in their intrinsic qualities, their most powerful recommendation. His moral precepts were, indeed, the

superstructure which it was natural to raise upon his doctrines. He had explained the true nature of God. He had purified from every species and degree of corruption, the notions which had been antecedently entertained of the Deity, and had represented Him as "a Spirit"—a Being to whom could not be attached even the idea of imperfection. He was not only aware that the duration of human life is limited and brief, but also that the terrestrial existence of mankind is intended as a preparative for an eternal state of being. He therefore endeavoured to induce his followers to keep this principle in view, in the whole system of their conduct. Thus do his instructions tend to elevate the human mind above every thing that is mean, and base, and sordid, and to impress the heart with the most generous feelings. He uniformly inculcates the maxims of peace and kind affection. He demands from his followers that liberality of disposition which will render easy to them every sacrifice which is necessary for the promotion of the general good; and that habitual self-restraint, which, keeping the mind of man in harmony within itself, constitutes the best preparative for the complete and faithful discharge of all the extensive variety of social obligations.

And the precepts of Jesus were illustrated and confirmed by his example. We are in possession of a minute account of the history both of his public and his private life. And what does this present to us, but a most interesting picture of piety to God, and benevolence to man? His biographers have recorded the confidential communications of his views and motives, which he from time to time made to his dearest friends, and his most intimate associates. And do these reveal any unworthy ends, or any sinister designs? Do they disclose any schemes of ambition, any detestable projects of selfish cupidity? His public and his private conduct are found, upon the closest scrutiny, to be strictly consistent. His sole aim is the improvement of the moral condition of mankind. For the promotion of this view, he is ready to sacrifice health,

ease, competence, reputation, and even life itself. Once more then, referring to the principle which I proposed to your consideration, in the case of the conduct of the first followers of Jesus, I would ask, is it probable—nay, is it, according to the known laws of human nature, possible, that he, who in despite of obloquy and suffering, was the advocate of purity, could be basely corrupt—that he, who braved death in its most terrific form, rather than retract his professions, could be, for worldly purposes, a selfish deceiver—in short, that the same individual could be at once the most fearless and consistent champion of virtue, and the most hypocritical and vicious of mankind?

On this consideration I would most willingly rest the whole argument as to the truth of Christianity; and I will conclude my letter by a suggestion which, though it would be invidious as regarding the community at large, I will venture, my dear son, to make to yourself. If at any time you waver in your belief of the divine obligation of Christian principles, strictly examine the existing tone and temper of your mind; and if you find that you think with reluctance of the practice of some duty which Christianity inculcates, or that you are inclined to indulge in some gratification which the law of Christ prohibits, guard yourself most cautiously, lest the obliquity of your will should have an unhappy influence on your judgment.

END OF VOL. II.

Structure & Functions of Man

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EXPLANATION OF THE FIGURES IN PLATE VII.

IN figure 1. is a front view of the skeleton, in which are given the names of the principal bones, as mentioned, with their offices, in the foregoing description. See Chap. xxvi. and xxvii.

Fig. 2. contains a view of the heart, with the adjacent blood-vessels of the thorax and abdomen.

A is the right ventricle of the heart: C is the left, which is scarcely visible. *e* the right auricle, the left being out of sight: at *a* is the origin of the pulmonary artery, which rises from the right ventricle, and divides itself into two branches that pass to the right and left lobes of the lungs: *b* the arch of the aorta, or great artery, that rises from the left ventricle, from which all the other arteries proceed, and by means of which the blood is carried to all parts of the body: *x* is the arteria innominata: E is the subclavian vein passing before the aorta, *y y* are the carotid arteries, which carry the blood to the upper parts of the body: *u u* are the jugular veins: *c* the superior vena cava: *i* is the inferior cava coming through the diaphragm: the aorta may be traced turning round the pulmonary artery and trachea to the spine, and running down upon its fore-part: it is seen again at *k*, called the descending aorta, sending out different branches to the abdominal viscera; as *l* the cæliac, *m* and *n* those to the mesentery: *o* and *p* the emulgent arteries, and *q*, *r* the emulgent veins, that go from the aorta and vena cava to the kidneys: *s*, *t*, *v*, the thoracic duct, which runs up by the side of the aorta, and appears again at *d*, where it terminates between the left jugular and subclavian vein: *h* is the trunk of the inferior vena cava.

Fig. 3. In this figure we have a view of the right ventricle and pulmonary artery laid open: *a* is a triangular flap of the fleshy side of the ventricle, turned back to expose the cavity: at *d* are the three semilunar valves in the mouth of the pulmonary artery, which is slit open.

Fig. 4 is a view of the lacrymal passages: *a a* are the puncta lacrymalia, from which the two lacrymal canals, *b b*, proceed to the sac *c* *d* is the large lacrymal duct, and *e* its opening into the nose.

Fig. 5 is a view of the ear: the external part is represented by A B: *a* is the back part of the meatus auditorius; of which the inner extremity is closed by a thin membrane *e*, called the

membrana tympani, which is set in a bony circle, like the head of a drum. Under this membrane runs a pair of nerves, *d*, called the chorda tympani. In the cavity are three distinct bones, viz. *b* the incus, *e* the malleus, and *d* the stapes.

Fig. 6 represents the anterior part of the ear, the cavity of the tympanum, its small bones, &c. *a* the malleus, *b* the incus, with its leg resting upon the stapes, *c* the membrana tympani, *d*, *e* the Eustachian tube. The sense of hearing is occasioned by a certain modulation of the air, collected in the external ear, and conveyed through the meatus auditorius to the membrana tympani. The auditory nerve, which is the seat of the sense of hearing, is distributed over the whole labyrinth.

EXPLANATION OF THE FIGURES IN PLATE VIII.

Fig. 1 and 2, contain a representation of several of the external muscles; the integuments, cellular membrane and fat, being removed: also the contents of the chest, abdomen, &c. Their names, and relative situation, are shewn in the figures: *x* in fig. 2, shews the lower part of the intestine leading to the rectum; 7 is the descending aorta; 8, the ascending vein; 9, the ureters.

Fig. 3, is a representation of the stomach and part of the intestinal canal, the arrows shew the course of the aliment: *a* is the end of the œsophagus; B the stomach; *h* the pylorus; *i*, *k*, *l*, &c. various convolutions of the small intestine, *r* is the rectum.

In Fig. 4, is an exhibition of the gall-bladder, biliary ducts and pancreas: *k* is the hepatic duct formed by various branches proceeding from the liver: *l* the cystic duct, which is the tube of communication between the hepatic duct *k*, and gall-bladder *i*: *n* is the ductus communis, or that part which forms a junction between the cystic and the duodenum, this latter being the first portion of the small intestine, which communicates at its origin with the stomach, through the pylorus: *p* is the pancreas, which is also connected with the beginning of the duodenum, in the cavity of which its excretory duct terminates: *q* represents a portion of the duodenum, with a longitudinal slit, being the opening for the united ducts.

Fig. 5 and 6, are the hand and foot, after they are stripped of the common integuments, to shew the muscles and tendons of the fingers and toes.

Plate VIII.
Vol. II. p. 568.

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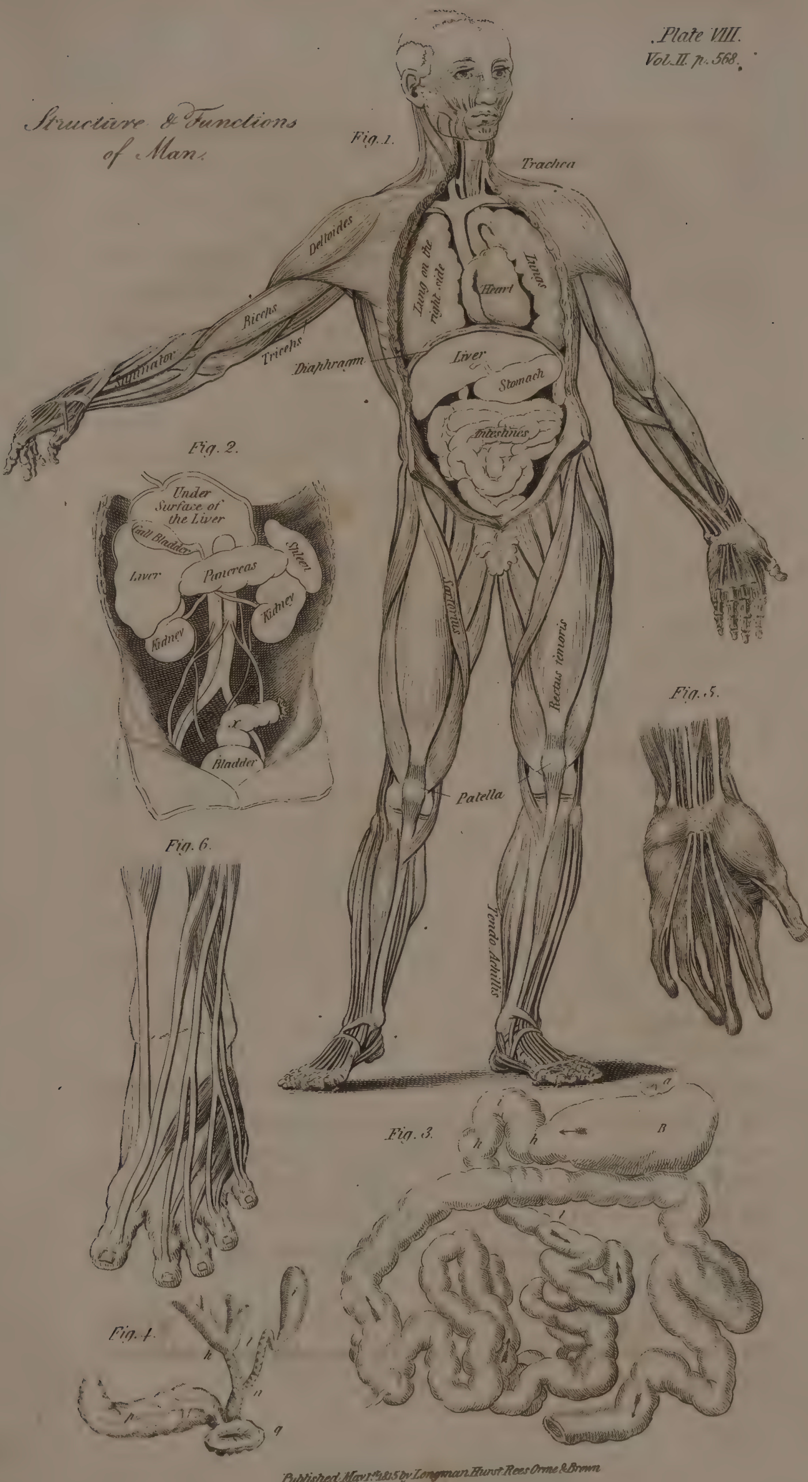

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